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APRIL - NOVEMBER 1992

# REPORT NO. 92-14

# CARISTRAP EVALUATION





Prepared for:
Office of the Project Manager,
Ammunition Logistics
ATTN: AMCPM-AL
Picatinny Arsenal, NJ 07806-5000

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**VALIDATION ENGINEERING DIVISION**
**SAVANNA, ILLINOIS 61074-9639**

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The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by the Office of the Project Manager, Ammunition Logistics (PM-AMMOLOG) to evaluate 1-1/4-inch Caristrap Weatherguard synthetic strapping material as a possible replacement for the metal strapping currently being used by the U.S. Army for ammunition unitization. A series of tests was conducted utilizing lab equipment and tactical vehicles to assess the suitability of the Caristrap as a replacement for steel strapping in unitization applications as well as a web-strap replacement in tiedown applications.

MIL-STD-1660, Design Criteria for Ammunition Unit Loads, tests were conducted on a 4,000-pound inertly loaded plywood pallet, 155mm projectile pallet, 8-inch projectile pallet, and a 40mm ammunition metal pallet. Strength evaluations, under extreme hot and cold conditions of the new Caristrap (continued)


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versus the Caristrap that had experienced accelerated aging during exposure to ultraviolet (UV) radiation. Road hazard testing was conducted using the Caristrap as a unitization strap and a tiedown strap on 155mm projectile pallets in a 2-1/2-ton truck. The Caristrap was also tested on a Unit Load Aviation Resupply Pallet (ULARP) loaded with thirty-eight 2.75-inch rocket containers and sixteen 20mm ammunition containers.

The results from the battery of tests that were performed on the Caristrap showed that the strapping is extremely vulnerable to both internal and external abrasion. Test results also showed that the Caristrap was vulnerable to UV radiation and would degrade over time if used on pallets that were placed in open storage. Results from tests used to estimate the lifetime of the strapping if used on a 5-ton truck traveling over rough terrain indicated that the strapping, when used on 155mm projectiles, would have an equivalent lifetime of 75 miles of travel. Test results also showed that the Caristrap would be suitable for use on ULARPs.

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL
VALIDATION ENGINEERING DIVISION
SAVANNA, IL 61074-9639

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CARISTRAP EVALUATION

APRIL - NOVEMBER 1992

TABLE OF CONTENTS

# PART 1

## INTRODUCTION

A. BACKGROUND. The U.S. Army Defense Ammunition Center and School (USADACS), Validation Engineering Division (SMCAC-DEV), was tasked by Office of the Project Manager, Ammunition Logistics (PM-AMMOLOG) to evaluate 1-1/4-inch Caristrap Weatherguard synthetic strapping material as a possible replacement for the metal strapping currently being used by the U.S. Army for ammunition unitization. A series of tests were conducted utilizing lab equipment and tactical vehicles to assess the suitability of the Caristrap as a replacement for steel strapping in unitization applications as well as a web-strap replacement in tiedown applications. The following tests were performed during the evaluation of the Caristrap: MIL-STD-1660, Design Criteria for Ammunition Unit Loads; environmental; road hazard; and Unit Load Aviation Resupply Pallet (ULARP).

B. AUTHORITY. The tests were accomplished IAW mission responsibilities delegated by U.S. Army Armament, Munitions and Chemical Command (AMCCOM), Rock Island, IL. Reference is made to the following:

1. Change 4, 4 October 1974, to AR740-1, 23 April 1973, Storage and Supply Activity Operation.

2. AMCCOM-R 10-17, Mission and Major Functions of USADACS, 13 January 1986.

C. OBJECTIVE. The objective of these tests was to determine if the Caristrap would be suitable as a direct replacement for the steel strapping that is currently being used to unitize ammunition on pallets.

D. CONCLUSIONS.

1. The Caristrap evaluated was too vulnerable to abrasion to be used as a direct replacement for steel strapping. In addition to the abrasion intolerance, the Caristrap was also vulnerable to ultraviolet (UV) radiation and would deteriorate with long-term exposure to sunlight.

2. If not properly applied, the Caristrap will loosen in a static state if a knot is not placed in the strap tail to prevent the strap from creeping back through the buckle (see drawing on page 6-3).

3. The elastic nature of the Caristrap would prevent the strapping from being used on most pallets that utilize top lift frames or can be top lifted.

4. During the evaluation of the Caristrap tensile strength, the buckle, used to connect the Caristrap, was determined to be limiting the ultimate strength of the Caristrap.

5. If not for the previously stated deficiencies, the Caristrap would be an extremely useful strap substitute for the following reasons:

(a) The Caristrap is safer to use than steel strapping because it has no sharp edges and will not lash-out at personnel when removing the straps like metal strapping does.

(b) The Caristrap requires only one tool for installation versus three tools for metal banding.

(c) The Caristrap can be removed with only a knife while steel strapping requires a band cutter for removal.

(d) The elastic properties of the Caristrap allow the strapping to remain tight even with a change in pallet size; i.e., pallet shrinkage or compression due to stacking.

6. The Caristrap would be a suitable substitute for web-straps in a ULARP application provided the loads were not assembled and then placed in long-term open storage where sunlight could deteriorate the Caristrap.

E. APPROVAL. As tested, the Caristrap Weatherguard synthetic strapping material cannot be approved for use on ammunition unit loads. Without protection from abrasion, the Caristrap can be quickly severed causing the ammunition unit load to fail.

F. RECOMMENDATION. The Caristrap performed well enough on the ULARP that further testing should be conducted to determine if the strapping could provide large-scale use on the larger 463L-type pallets. Future considerations should also be given any new developments that the Caristrap International, Incorporated might develop that would increase the abrasion tolerance of the synthetic strapping.

PART 2

APRIL - NOVEMBER 1992

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## PART 3

## TEST PROCEDURES

The following test procedures were utilized during the evaluation of the Caristrap.

A. MIL-STD-1660. The test procedures outlined in this section were extracted from MIL-STD-1660, Design Criteria for Ammunition Unit Loads, 8 April 1977. This standard identifies nine steps that a unitized load must undergo if it is considered to be acceptable. The five tests that were conducted on the test specimen are synopsized below.

1. SUPERIMPOSED LOAD TEST. The unit load was loaded to simulate a stack of identical unit loads stacked 16 feet high for a period of one hour, as specified in Method 5016, Federal Standard 101. This stacking load was simulated by subjecting the unit load to a compression of weight equal to an equivalent 16-foot stacking height. The compression load was calculated in the following manner. The unit load weight was multiplied by 192 minus the unit height in inches, divided by the unit height in inches, then multiplied by a safety factor of two. The resulting number is the equivalent compressive force of a 16-foot-high load.

2. REPETITIVE SHOCK TEST. The repetitive shock test was conducted IAW Method 5019, Federal Standard 101. The test procedure is as follows: The test specimen was placed on, but not fastened to, the platform. With the specimen in one position, the platform was vibrated at 1/2-inch amplitude (1-inch double amplitude) starting at a frequency of approximately 3 cycles-per-second. The frequency was steadily increased until the package left the platform. The resonant frequency is achieved when a 1/16-inch-thick feeler gage was momentarily slid freely between every point on the specimen in contact with the platform at some instance during the cycle or a platform acceleration achieved 1+0.1G. Midway into the testing period, the specimen was rotated 90 degrees, and the test continued for the duration. Unless failure

occured, the total time of vibration was two hours if the specimen was tested in one position; and, if tested in more than one position, the total time was three hours.

3. EDGEWISE ROTATIONAL DROP TEST. This test was conducted by using the procedures of Method 5008, Federal Standard 101. The procedure for the edgewise rotational drop test is as follows: The specimen was placed on its skids with one end of the pallet supported on a beam 4 1/2-inches high. The height of the beam was increased, when necessary, to ensure that there was no support for the skids between the ends of the pallet when dropping took place, but was not high enough to cause the pallet to slide on the supports when the dropped end was raised for the drops. The unsupported end of the pallet was then raised and allowed to fall freely to the concrete, pavement, or similar underlying surface from a prescribed height. Unless otherwise specified, the height of drop for level A protection conformed to the following tabulation:

| GROSS WEIGHT NOT EXCEEDING | DIMENSIONS ON ANY EDGE NOT EXCEEDING | HEIGHT OF DROP LEVEL A PROTECTION |
|---|---|---|
| POUNDS | INCHES | INCHES |
| 600 | 72 | 36 |
| 3,000 | no limit | 24 |
| no limit | no limit | 12 |

4. SLING COMPATIBILITY TEST. Unit loads utilizing special design for nonstandard pallets were lifted, slung, lowered, and otherwise handled as necessary using slings of the types normally used for handling the unit loads under consideration. Slings were easily attached and removed. Danger of slippage or disengagement when the load was suspended was cause for rejection of the unit load.

5. INCLINE-IMPACT TEST. This test was conducted by using the procedure of Method 5023, Incline-Impact Test of Federal Standard 101. The procedure for the incline-impact test is as follows: The specimen was placed on the carriage with the surface or edge which was to be impacted projecting at least two inches beyond the front end of the carriage. The carriage was brought to a predetermined position on the incline and released. If it is desired to concentrate the impact on any particular position on the container, a 4- by 4-inch timber may be attached to the bumper in the desired position before the test. No part of the timber was struck by the carriage. The position of the container on the carriage and the sequence in which surfaces and edges are subjected to impacts may be at the option of the testing activity and will depend upon the objective of the tests. When the test is to determine satisfactory requirements for a container or pack, and, unless otherwise specified, the specimen shall be subjected to one impact on each surface that has each dimension less than 9.5 feet. Unless otherwise specified, the velocity at time of impact was 7 feet-per-second.

B. HOT/COLD TENSILE STRENGTH EVALUATION OF NEW VERSUS ULTRAVIOLET (UV)-AGED STRAPPING.

1. UV ACCELERATED AGING. UV accelerated aging process was accomplished utilizing a carbon-arc-type Atlas weatherometer. Caristrap samples were placed in the weatherometer on a rotating frame (see page 7-6). The machine was set up to provide continuous light exposure as well as intermediate moisture exposure to the Caristrap samples according to American Society for Testing Materials (ASTM) G23-90, Test Method 1. Moisture exposure was set to occur every two hours for a duration of 10 minutes. Chamber temperature exposure was maintained at 145 degrees Fahrenheit per the test specification. The machine was operated at a carbon-arc voltage of 220 volts which resulted in an arc current of 65 AMPS. Caristrap samples were removed from the machine at intervals of 100, 200, 300, and 400 hours of exposure to the UV radiation and tested to determine if the strapping tensile

strength had decreased. The manufacturer of the weatherometer was contacted, and he indicated that two hours of UV exposure in the machine was equivalent to one day of exposure in Miami, FL.

2. TEMPERATURE PRECONDITIONING. For tensile strength evaluations at temperatures other than room temperature (70 degrees Fahrenheit), the following procedure was followed. The test sample was placed in the test fixture which was located inside of a small environmental unit (see page 7-7). The test sample and fixture were then exposed to the desired test temperature for a period of 20 minutes after the chamber reached the desired temperature. After 20 minutes of exposure, the Caristrap was then pulled to failure utilizing the procedure detailed in paragraph 3.

3. TENSILE STRENGTH MEASUREMENT. The tensile strength of the Caristrap was determined by placing a sample of the Caristrap inside the test fixture (see page 7-7 and drawing on page 6-2). If required, the Caristrap received temperature preconditioning as described above. At the desired temperature, the test fixtures were pulled apart at a rate of 10 inches per minute. During the pull test, the tension in the strap was monitored with a loadcell connected to the upper test fixture. Upon completion of the test, the peak force measured during the breaking of the Caristrap was recorded as the tensile strength of the strap.

## C. TRANSPORTABILITY TESTING.

1. Road testing is accomplished to ensure loads of ammunition are properly secured to prevent damage to the ammunition item and/or the transport vehicle. The road test was performed using inertly-loaded items which were equal in weight, correctly located at the center of gravity, and general in character to the material ultimately being transported. The test load

was subjected to USADACS five-step transportability road course identified herein and depicted on page 3-6.

a. Step No. 1. This step provided for the specimen load to be driven over a 200-foot-long segment of concrete-paved road which consisted of two series of railroad ties projecting 6 inches above the level of the road surface. This hazard course was traversed two times.

(1) The first series of ties was spaced on 8-foot centers and alternately positioned on opposite sides of the road centerline for a distance of 50 feet.

(2) Following the first series of ties, a 75-foot paved roadway separated the first and second series of railroad ties.

(3) The second series of ties was alternately positioned similarly to the first, but spaced on 10-foot centers for a distance of 50 feet.

(4) The specimen load was driven across the road hazard course at speeds that produced the most violent vertical and side-to-side rolling reaction obtainable in traversing the road hazard course (approximately 5 mph).

b. Step No. 2. This step consisted of 30 miles of travel over available rough roads consisting of gravel, concrete and asphalt, curves, cattle gates, and stops and starts.

c. Step No. 3. This step provided for the specimen load to be subjected to three full air brake stops while traveling in the forward direction and one in the reverse direction while traveling down a 7 percent grade. The first three stops were at speeds of 5, 10, and 15 mph, while the stop in the reverse direction was approximately 5 mph.

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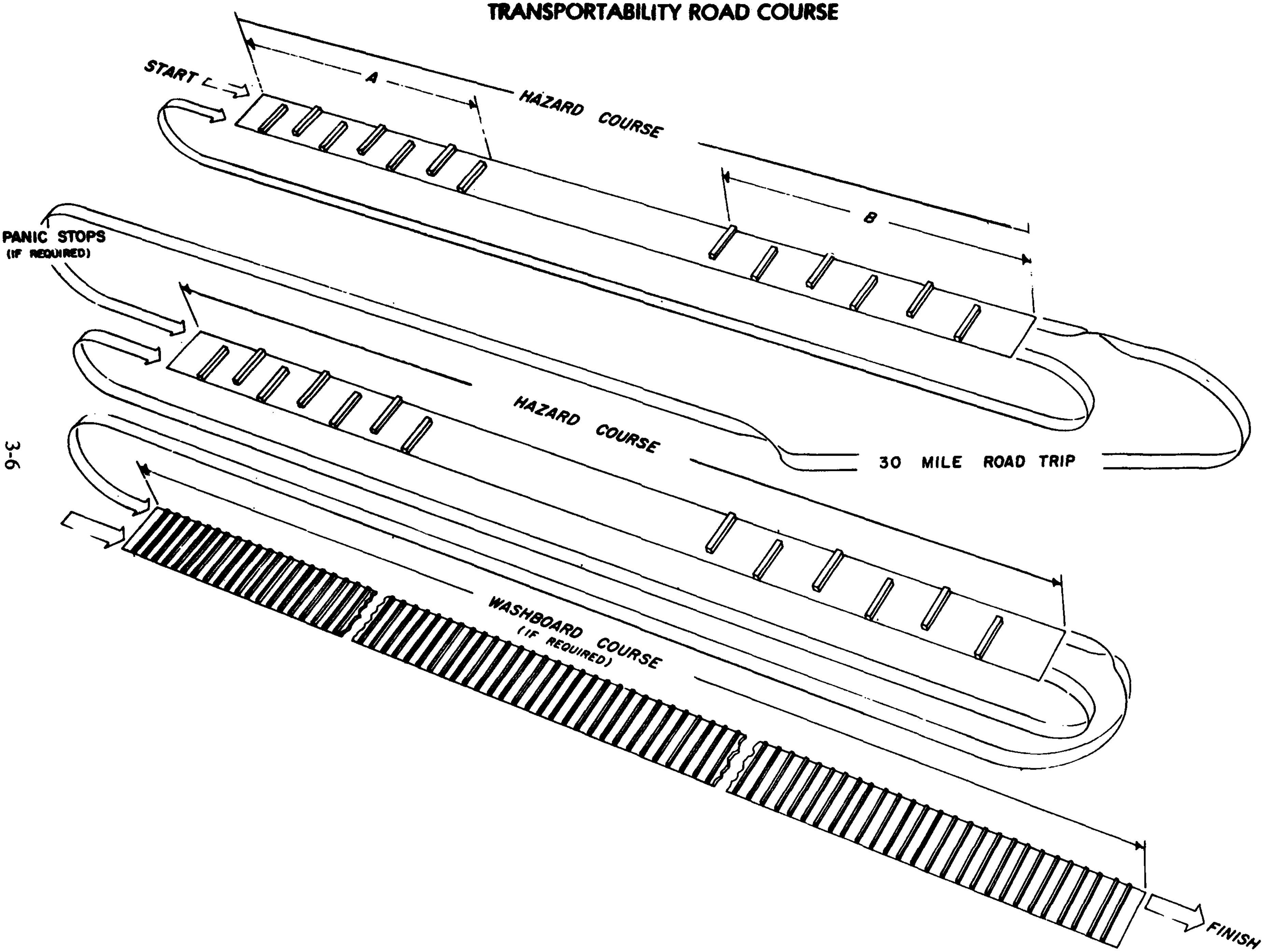
### TRANSPORTABILITY ROAD COURSE



d. Step No. 4. This step consisted of a repeat of Step No. 1.

e. Step No. 5. This step provided for the specimen load to be driven over a 300-foot-long segment of concrete-paved road which had rails spaced on 26 1/2-inch centers and protruded two inches above the road surface. The specimen load was driven at a speed which produced the most violent response.

NOTE: Steps Nos. 3 and 5 may be deleted at the discretion of the test engineer.

2. INSPECTION AND DATA COLLECTION. At selected intervals during testing, thorough inspections of the specimen loads were made by technically proficient personnel to collect data on the specimen load and equipment resulting from above load test steps. The data are recorded in part 4, following.

D. ULARP EVALUATION TEST.

1. INCLINE UNLOADING TEST. The incline unloading test was performed to determine if the ULARP loads could withstand an inclined drop impact from a Chinook (CH-47) helicopter. The test was performed utilizing a Palletized Loading System (PLS) truck, a PLS flatrack, and four sections of roller conveyer. After securing the conveyers to the PLS flatrack, the aviation pallet was placed on the conveyer and secured to the flatrack utilizing a quick-release hook. The flatrack was then elevated to a 10 degree angle with respect to the ground. Next, the quick-release hook was tripped allowing the pallet to roll approximately 10 feet down the flatrack where it struck the ground. Just prior to striking the ground, the PLS truck began to pull forward at a rate of approximately 3 mph. Upon completion of the test, the ULARP load was inspected for excessive shifting and damage.

2. TRANSPORTABILITY TESTING. As described in part 3.C.

E. <u>TRUCK TRANSPORTATION SIMULATION</u>. The truck transportation simulation was conducted in order to estimate the mileage lifetime of the Caristrap on 155mm projectile pallets and 120mm ammunition pallets being transported by an M813 5-ton cargo truck. The simulation was conducted in a procedure similar to that outlined in test report, Realistic Test Schedules for Secured Cargo in Military Vehicles Groups I and II, U.S. Army Combat Systems Test Activity (USACSTA), STECS-EN-EV, January 1984. In order to conduct the simulation, a low frequency, 0 - 5 Hz, 1-inch double amplitude sinusoidal vibration table was operated at 300 rpm with a simulated truck load of 155mm projectile pallets and 120mm ammunition pallets (see photos 7-8 through 7-12). During the test, the Caristrap unitized pallets were monitored for wear due to interaction with the other pallets. As outlined in the USACSTA report, 10 minutes of vibration at 300 rpm for a load orientation parallel with the direction of motion and 10 minutes of vibration at 300 rpm for a load orientation perpendicular with the direction of motion would be equivalent to 240 km of M813 5-ton cargo truck transportation, 22 percent of which is considered to be rough terrain.

# PART 4

## TEST RESULTS

A. MIL-STD-1660 TEST RESULTS.

1. 4,000-POUND LOADED PLYWOOD PALLET. The 4,000-pound inertly loaded plywood pallet was unitized with five pieces of Caristrap (see pages 7-2 and 7-3). MIL-STD-1660 testing was then conducted on the pallet. The pallet failed MIL-STD-1660 tests due to the severing of one of the Caristrap samples during the repetitive shock test.

(a) STACKING TEST. The test pallet was compressed with a force of 43,000 pounds for one hour. No damage was sustained by the pallet or the Caristrap samples.

(b) REPETITIVE SHOCK TEST. The 4,000-pound loaded pallet was placed on the shaker table in the longitudinal direction where it was vibrated at 260 rpm. Five minutes into the test, one of the pieces of Caristrap, that was perpendicular to the direction of rotation, was severed due to the repetitive shifting of the pallet load with respect to the pallet base. No further testing was conducted on the 4,000-pound pallet.

2. 155MM PROJECTILE PALLET. A 155mm projectile pallet was unitized with two pieces of Caristrap (see page 7-4). The pallet was 29 3/4-inches high and weighed 820 pounds. The pallet was considered very marginal due to the partial severing of one of the Caristrap samples during the repetitive shock test of MIL-STD-1660 testing.

(a) STACKING TEST. The test pallet was compressed with a force of 8,950 pounds for a period of one hour. No damage was noted to the pallet or the Caristrap samples at the completion of the stacking test.

(b) <u>REPETITIVE SHOCK TEST</u>. The test pallet was placed on the vibration table in the longitudinal orientation. Due to the sensitivity of the Caristrap to abrasion, special wooden gates had to be constructed on the vibration table to prevent the Caristrap from contacting any part of the vibration table. In the instances where the Caristrap was allowed to rub on the gates of the vibration table, the strap was severed within only a few minutes of vibration. The pallet was vibrated at 125 rpm for a period of 90 minutes. At the end of the first 90 minutes on the vibration table, one piece of Caristrap was partially severed from repetitive rubbing with a plastic grommet on one of the 155mm rounds. The pallet was then rotated to the lateral orientation and vibrated at 100 rpm for 90 minutes. No additional damage was noted at the end of the second orientation on the vibration table.

(c) <u>EDGEWISE ROTATIONAL DROP TEST</u>. One end of the pallet was placed on a section of 2- by 4-inch lumber and the opposite end of the pallet was raised 7 inches for the longitudinal drops and 5 inches for the lateral drops. No change was noted in the pallet condition as a result of this test.

(d) <u>SLING COMPATIBILITY TEST</u>. The pallet was top lifted from four corner points, two points on a longitudinal edge, two points on a lateral edge, and one corner point. No damage to the pallet or Caristrap was noted at the completion of this test.

(e) <u>INCLINED-IMPACT TEST</u>. Due to the dimensions of the pallet, the 155mm projectile pallet was only impacted in the longitudinal direction. No additional damage was sustained by the pallet as a result of this test.

3. <u>EIGHT-INCH PROJECTILE PALLET</u>. An 8-inch projectile pallet was unitized with three pieces of Caristrap (see page 7-5). The pallet was 47 1/4-inches high and weighed 1,250 pounds. The pallet failed MIL-STD-1660 tests due to the fact that the projectiles failed to

remain in the plywood base during the edgewise rotational drop test and the sling compatibility test.

(a) STACKING TEST. The projectile pallet was compressed by a static force of 7,700 pounds for a period of one hour. At the end of one hour of compression, inspection of the pallet revealed no damage to the pallet or the Caristrap.

(b) REPETITIVE SHOCK TEST. The test pallet was placed on the vibration table in the longitudinal orientation. Due to the sensitivity of the Caristrap to abrasion, special wooden gates had to be constructed on the vibration table to prevent the Caristrap from contacting any part of the vibration table. In the instances where the Caristrap was allowed to rub on the gates of the vibration table, the strap was severed within only a few minutes of vibration. The pallet was vibrated at 150 rpm for 90 minutes. At the completion of the first 90 minutes, no damage was noted to have occurred on the pallet or the Caristrap. The pallet was then rotated 90 degrees to the lateral orientation and vibrated at 125 rpm for 90 minutes. No change in pallet or Caristrap condition was noted at the end of the second 90 minutes.

(c) EDGEWISE ROTATIONAL DROP TEST. One end of the pallet was placed on a section of 2- by 4-inch lumber and the opposite end of the pallet was raised 12 inches for the longitudinal drops and 11 inches for the lateral drops. During the drop tests, several of the projectiles were dislodged from the plywood base and had to be readjusted. No damage occurred to the pallet or the Caristrap.

(d) SLING COMPATIBILITY TEST. The pallet was top lifted from four corner points, two points on a longitudinal edge, two points on a lateral edge, and one corner point. During the pallet slinging test, the projectiles that were being used as the lifting points were dislodged from the plywood base due to the elastic nature of the strapping.

(e) INCLINED-IMPACT TEST. The pallet was inclined-impact tested on all four sides. No additional shifting of the projectiles was noted during this test.

4. 40MM AMMUNITION METAL PALLET. A 40mm ammunition metal pallet load was unitized with two pieces of Caristrap. The pallet was 36-1/4-inches high and weighed 2,650 pounds. This pallet failed MIL-STD-1660 tests. During the sling compatibility test, the Caristrap samples stretched allowing the top lift frame to be pulled from the top of the load 1-1/2- to 2-inches. While the load did remain intact, the top lift frame had separated enough to allow the containers to be removed.

(a) STACKING TEST. The metal pallet was compressed by a static force of 22,800 pounds for a period of one hour. At the end of one hour of compression, inspection of the pallet revealed no damage to the pallet or the Caristrap samples.

(b) REPETITIVE SHOCK TEST. During the longitudinal orientation, the 40mm ammunition metal pallet was vibrated at 170 rpm for 90 minutes. At the completion of the first 90 minutes, no Caristrap or pallet damage was noted. The pallet was then rotated 90 degrees to the lateral orientation and vibrated at 195 rpm for 90 minutes. No Caristrap or pallet damage was noted.

(c) EDGEWISE ROTATIONAL DROP TEST. One edge of the pallet was placed on a 6-inch-high beam and the other edge of the pallet was raised 24 inches for the longitudinal and lateral drops. Upon completion of the edgewise rotational drops, the pallet and strapping were inspected and found to have suffered no damage.

(d) SLING COMPATIBILITY TEST. The pallet was top lifted from four corner points, two points on a longitudinal edge, two points on a lateral edge, two diagonal points, and one corner point. During the sling lifts of two points or less, the Caristrap stretched allowing the top lift frame to separate from the containers 1-1/2- to 2-inches. All containers remained unitized, but the top lift frame had separated from the containers enough to allow for container removal.

(e) INCLINED-IMPACT TEST. The pallet was inclined-impact tested on all four sides. No pallet or Caristrap damage was noted upon completion of the impacts.

B. HOT/COLD TENSILE STRENGTH EVALUATION OF NEW VERSUS UV-AGED STRAPPING. During the initial tensile strength evaluations, the Caristrap samples were broken utilizing two fixtures that allowed the Caristrap to be looped around two pins and then connected with the Caristrap buckle. Initial readings, as well as visual inspection, showed that the buckle was limiting the overall strength of the Caristrap. When the Caristrap was tested, the degree of compression of the buckle was of a large enough magnitude that it cut the Caristrap before reaching the ultimate strength of the material. Results from this test method indicated that the average Caristrap strength was only 2,745 pounds. This value was over 370 pounds less than the average tensile strength obtained with the test setup that was ultimately used. The modified test setup that was used utilized two pins and half of a figure-eight wrapping pattern (see drawing on page 6-2).

1. EFFECT OF TEMPERATURE ON TENSILE STRENGTH OF NEW CARISTRAP. The new Caristrap was tested at -50, 0, 70, 100, 150, and 200 degrees Fahrenheit. Ten Caristrap samples were broken at each temperature (see part 5). Results from this evaluation indicated that the tensile strength of the Caristrap was significantly decreased as the temperature of the Caristrap increased. The average breaking strength of the Caristrap at -50 degrees Fahrenheit was 4,235 pounds while the average breaking strength of the Caristrap at 200 degrees Fahrenheit was 1,960 pounds.

2. EFFECT OF UV RADIATION ON TENSILE STRENGTH OF CARISTRAP. Caristrap samples were aged in the Atlas weatherometer and tested at 100, 222, 322, and 422 hours of UV exposure (422 hours is equivalent to 211 sunny days of exposure in Miami, FL.). Ten Caristrap samples of each duration of exposure were tested at 70 degrees Fahrenheit to determine the tensile strength. Results from these tests indicated that UV radiation would cause the tensile strength of the Caristrap to decrease. The average breaking strength of the new Caristrap was 3,115 pounds while the average tensile strength of the Caristrap at 422 hours of exposure was 2,675 pounds.

3. EFFECT OF TEMPERATURE ON UV-AGED CARISTRAP. Caristrap samples that had received 422 hours of UV exposure were tested at -50, 0, 70, 100, 150, and 200 degrees Fahrenheit. Ten Caristrap samples that had been aged 422 hours were tested at each of the test temperatures. Results from these tests indicated that the UV exposure did not change the temperature versus tensile strength characteristics. As with the new Caristrap sample, the sample that was exposed to 422 hours of UV radiation still exhibited a large decrease in strap strength as the temperature was increased. The average Caristrap strength at -50 degrees Fahrenheit was 3,010 pounds while the average strap strength at 200 degrees Fahrenheit was 1,740 pounds.

C. TRUCK TRANSPORTATION SIMULATION.

1. 155MM PROJECTILE PALLETS. Two attempts were made to estimate the mileage lifetime of the Caristrap on 155mm projectile pallets being transported in a 5-ton cargo truck. During the first test, six 155mm projectile pallets unitized with three Caristrap sample per pallet were secured to the vibration table in an orientation with the row of six pallets perpendicular to the direction of motion (see page 7-8). During the first orientation, the first Caristrap was severed after only 6 minutes and 30 seconds of vibration at 300 rpm (see page 7-10). After the

first 10 minutes of the perpendicular orientation, 5 Caristrap samples had been severed and 2 more were partially severed. The pallets were then rotated to the orientation with the row of six pallets parallel to the direction of motion (see page 7-9). During the second orientation, the first Caristrap sample was severed after only 2 minutes and 20 seconds of vibration. The test was stopped at this point to prevent the projectiles from being dislodged from the pallets. A more detailed inspection revealed an additional four broken Caristrap samples and one partially cut Caristrap. An accurate estimate for the mileage lifetime of the Caristrap on 155mm projectiles was not determined due to the fact that an equal amount of vibration was not obtained in the parallel orientation that had been obtained in the perpendicular orientation.

During the second test, the six 155mm projectile pallets were rebanded with new Caristrap samples and placed on the shaker table in the parallel orientation. During the parallel orientation, one Caristrap was severed after only 1 minute of vibration at 300 rpm. The test was stopped after three minutes in order to prevent the projectiles from becoming dislodged from the pallets. Inspection of the pallets revealed a total of nine straps severed and four additional straps were partially severed. Again, a mileage estimate was not available due to the fact that the second orientation was not conducted.

2. <u>120MM AMMUNITION METAL PALLETS</u>. Two attempts were made to estimate the mileage lifetime of the Caristrap on 120mm ammunition metal pallets being transported in a 5-ton cargo truck. During the first test, two 120mm ammunition metal pallets unitized with three Caristrap samples per pallet were secured to the vibration table in an orientation with the row of two pallets parallel to the direction of motion of the vibration table (see page 7-11). During the first orientation, the first Caristrap was severed after only seven minutes of operation. At the completion of the first 10 minutes, inspection of the pallets revealed that the other Caristrap samples were partially cut. The pallets were then rotated to the orientation with

the row of two pallets perpendicular to the direction of motion (see page 7-12). After 30 seconds of operation in the second orientation, an additional Caristrap was severed on the pallet that had a Caristrap severed during the first orientation. The test was halted after four minutes of operation due to vibration table malfunction. Since the Caristrap was unable to withstand the 10-minute timeframes for each orientation, the decision was made to redo the test utilizing only 5-minute timeframes for each orientation in order to obtain an estimate of the mileage lifespan of the Caristrap.

During the second test, the two 120mm ammunition metal pallets were rebanded with new Caristrap samples and placed on the shaker table in an orientation with the row of two pallets parallel to the direction of motion. The vibration table was operated for 5 minutes at 300 rpm. At the completion of the first orientation, the Caristrap samples were determined to have suffered minor abrasions. The pallets were then rotated to an orientation with the row of two pallets perpendicular to the direction of motion and vibrated another five minutes. At the completion of the second orientation, the Caristrap samples were inspected and found to have passed the test, which indicated that the Caristrap would have an approximate lifetime of 75 miles of travel in a 5-ton truck.

D. ULARP EVALUATION. A ULARP load consisting of thirty-eight 2.75-inch rocket containers and sixteen 20mm containers was assembled and tied down with 11 Caristrap samples on a 463L/INTEX pallet (see pages 7-13 through 7-17). During the evaluation, the bundling strap around the 20mm ammunition containers was severed. The pallet was still considered to have passed the incline unloading test and the road hazard tests due to the fact that the containers were still secured to the pallet by the Caristrap overtop of the containers. In the event the Caristrap was ever used for this particular load, bundling straps that went around each stack of containers horizontally would be preferable, rather than one strap around the containers vertically.

Road Test Data from Test No. 5 Date: 29 June 1992

Cobra Load 2:

Load weight: 9,100 pounds.

10 Degree Incline Unloading Test: The incline unloading test resulted in the entire load shifting 5 1/2-inches until it was against the tiedown rings. No damage was sustained by any of the Caristrap samples.

Pass 1, Course A: 5.62 seconds, 6.07 mph.

Pass 1, Course B: 5.41 seconds, 6.30 mph.

Remarks: Load shifted forward 1/2-inch. Lateral straps overtop the 2.75-inch rocket containers were separated. Minor cutting of Caristrap samples overtop 20mm ammunition containers.

Pass 2, Course A: 5.49 seconds, 6.21 mph.

Pass 2, Course B: 5.56 seconds, 6.13 mph.

Remarks: Load shifted right 1/2-inch. Bundling strap around 20mm ammunition containers was severed. No change in the remainder of the Caristrap samples was noted.

30-Mile Road Test: No additional load movement or Caristrap damage was noted at the completion of the test.

Panic Stops: Several inches of racking in the load was noted during the panic stops. At the completion of the stops, no permanent load movement or Caristrap damage was evident.

Pass 3, Course A: 5.53 seconds, 6.16 mph.

Pass 3, Course B: 5.36 seconds, 6.36 mph.

Remarks: No significant load movement was noted. The 20mm ammunition containers outside of the 2.75-inch rocket containers shifted forward. All Caristrap samples remained tight.

Pass 4, Course A: 5.51 seconds, 6.19 mph.

Pass 4, Course B: 5.43 seconds, 6.28 mph.

Remarks: No changes noted at the completion of the fourth pass.

Washboard Course: 58 seconds, 3.53 mph.

Remarks: Three strands of one Caristrap overtop of the 20mm ammunition containers were noted to be cut at the completion of the washboard course. One of the Caristrap samples overtop of the 2.75-inch rocket containers was also noted to have a strand cut. The remainder of the Caristrap samples were also showing signs of internal scuffing. No load movement was noted at the completion of the test.

E. TRANSPORTABILITY TESTING.

1. 155MM PROJECTILES UNITIZED WITH METAL STRAPPING AND TIED DOWN WITH CARISTRAP. The 155mm projectile pallets were unitized with three metal bands and tied down in an M35 series 2-1/2-ton truck with six Caristrap samples (see pages 7-18 through 7-20). The truck was operated over the road hazard course according to the procedures outlined

in part 4. The test was considered a failure due to the toppling of the front row of pallets during the panic stops.

Road Test Data                                                                 Date: 16 July 1992

Load weight: 5,280 pounds.

Pass 1, Course A: 6.40 seconds, 5.33 mph.

Pass 1, Course B: 6.80 seconds, 5.01 mph.

Remarks: Load shifted left 3.5 inches and forward 1 inch. Back row of pallets had nearly jumped over the back retaining strap around the skids of the back row of pallets.

Pass 2, Course A: 4.19 seconds, 8.14 mph.

Pass 2, Course B: 4.49 seconds, 7.59 mph.

Remarks: Load shifted left an additional 3-3/8-inches. Back row of pallets shifted back an additional inch and had totally jumped over the back retaining strap around the skids of the back row of pallets.

30-Mile Road Test: Load shifted left an additional 1/8-inch.

Panic Stops: During the first panic stop, the front row of 155mm projectile pallets nearly toppled over. During the second panic stop, the front row of 155mm projectile pallets toppled over. No further testing was conducted. The elastic properties of the Caristrap were determined to be the cause of failure.

2. 155MM PROJECTILES UNITIZED WITH CARISTRAP AND TIED DOWN WITH WEB STRAPS. The 155mm projectiles were unitized with three Caristrap samples per pallet and tied down in an M35 series 2-1/2-ton truck with six web straps (see pages 7-21 through 7-23). The truck was operated over the road hazard course according to the procedures outlined in part 4. Upon completion of the tests, the Caristrap was inspected and no major abrasions were noted.

Road Test Data Date: 2 November 1992

Load weight: 5,280 pounds

Pass 1, Course A: 5.67 seconds, 6.01 mph.

Pass 1, Course B: 5.61 seconds, 6.08 mph.

Remarks: Front pallets shifted forward 1/2-inch. Caristrap samples remained tight.

Pass 2, Course A: 6.60 seconds, 5.17 mph.

Pass 2, Course B: 5.60 seconds, 6.09 mph.

Remarks: Back pallets shifted forward 1/2-inch. Front pallets shifted right 1/2-inch. Caristrap samples remained tight and undamaged.

30-Mile Road Test: No change in pallet position or strap condition as a result of the 30-mile road test.

Panic Stops: Minor racking of the pallets during the stops, but no permanent movement of the pallets was noted.

Pass 3, Course A: 6.39 seconds, 5.34 mph.

Pass 3, Course B: 6.13 seconds, 5.56 mph.

Remarks: No change in pallet position or strap condition was noted.

Pass 4, Course A: 6.21 seconds, 5.49 mph.

Pass 4, Course B: 6.04 seconds, 5.64 mph.

Remarks: No change in pallet position or strap condition was noted.

Washboard Course: 72.84 seconds, 2.81 mph.

Remarks: No change in pallet position or strap condition was noted.

PART 5

## CARISTRAP TENSILE STRENGTHS

Tensile Strengths at 70 Degrees Fahrenheit

| New Condition | 100 Hrs UV Aging | 222 Hrs UV Aging | 322 Hrs UV Aging | 422 Hrs UV Aging |
|---|---|---|---|---|
| 3000 | 2900 | 2700 | 2800 | 2500 |
| 3100 | 2700 | 2700 | 2700 | 2850 |
| 3050 | 2900 | 2700 | 2700 | 2900 |
| 3150 | 2900 | 2700 | 2700 | 2650 |
| 3150 | 2850 | 2700 | 2600 | 2700 |
| 3150 | 2850 | 2400 | 2550 | 2700 |
| 3150 | 2750 | 2550 | 2650 | 2550 |
| 3150 | 2900 | 2800 | 2550 | 2600 |
| 3100 | 2850 | 2700 | 2600 | 2600 |
| 3150 | 3050 | 2550 | 2650 | 2700 |
| Average: | | | | |
| 3115 | 2865 | 2650 | 2655 | 2675 |

New Caristrap Tested at Extreme Temperatures

| New -50 | New 0 | New 100 | New 150 | New 200 |
|---|---|---|---|---|
| 4400 | 4000 | 3000 | 2550 | 1900 |
| 4300 | 4100 | 2950 | 2300 | 2000 |
| 4300 | 4100 | 2900 | 2450 | 1850 |
| 4200 | 3850 | 2800 | 2400 | 1900 |
| 4150 | 4000 | 2800 | 2700 | 2050 |
| 4300 | 4000 | 2950 | 2500 | 2000 |
| 4200 | 4000 | 2850 | 2400 | 2000 |
| 4250 | 3950 | 2850 | 2600 | 1900 |
| 4200 | 4100 | 2900 | 2350 | 2050 |
| 4050 | 4000 | 2800 | 2350 | 1950 |

Average:

| | | | | |
|---|---|---|---|---|
| 4235 | 4010 | 2880 | 2460 | 1960 |

Caristrap Aged 422 Hours in UV Chamber Tested at Extreme Temperatures

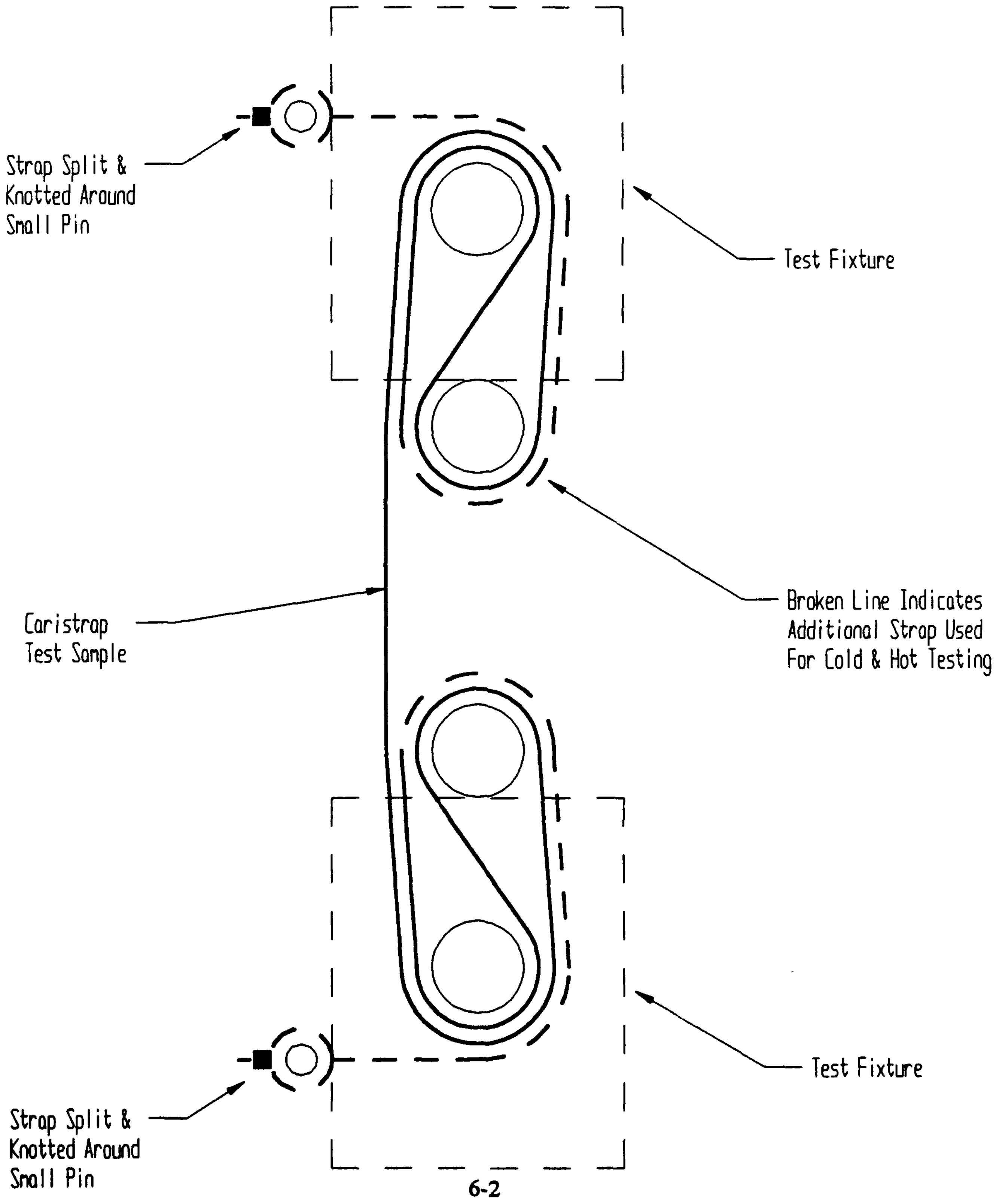
| -50 | -0 | 100 | 150 | 200 |
|---|---|---|---|---|
| 2700 | 3000 | 2300 | 1900 | 1700 |
| 3200 | 3000 | 2500 | 2150 | 1800 |
| 3050 | 3000 | 2300 | 2150 | 1600 |
| 3100 | 2950 | 2600 | 2200 | 1700 |
| 3200 | 3000 | 2450 | 2150 | 1750 |
| 3150 | 2950 | 2400 | 2100 | 1800 |
| 3050 | 3000 | 2600 | 2100 | 1700 |
| 2850 | 2600 | 2400 | 2050 | 1800 |
| 3000 | 2850 | 2450 | 2050 | 1850 |
| 2800 | 3000 | 2200 | 2150 | 1700 |
| Average: | | | | |
| 3010 | 2935 | 2420 | 2100 | 1740 |

Note: All values are in pounds or degrees Fahrenheit

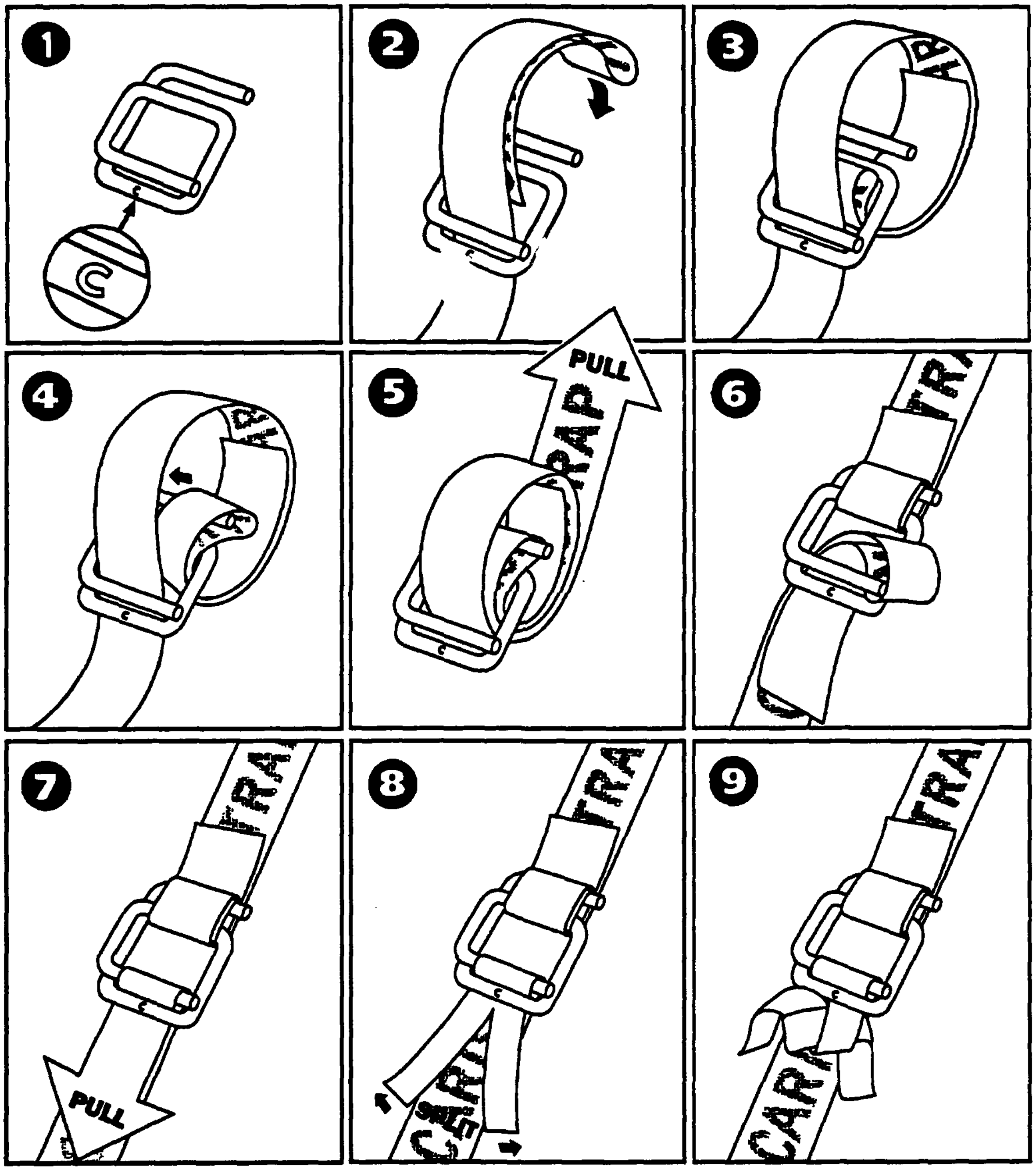
PART 6

DRAWINGS

CARISTRAP TENSILE STRENGTH
EVALUATION TEST FIXTURES

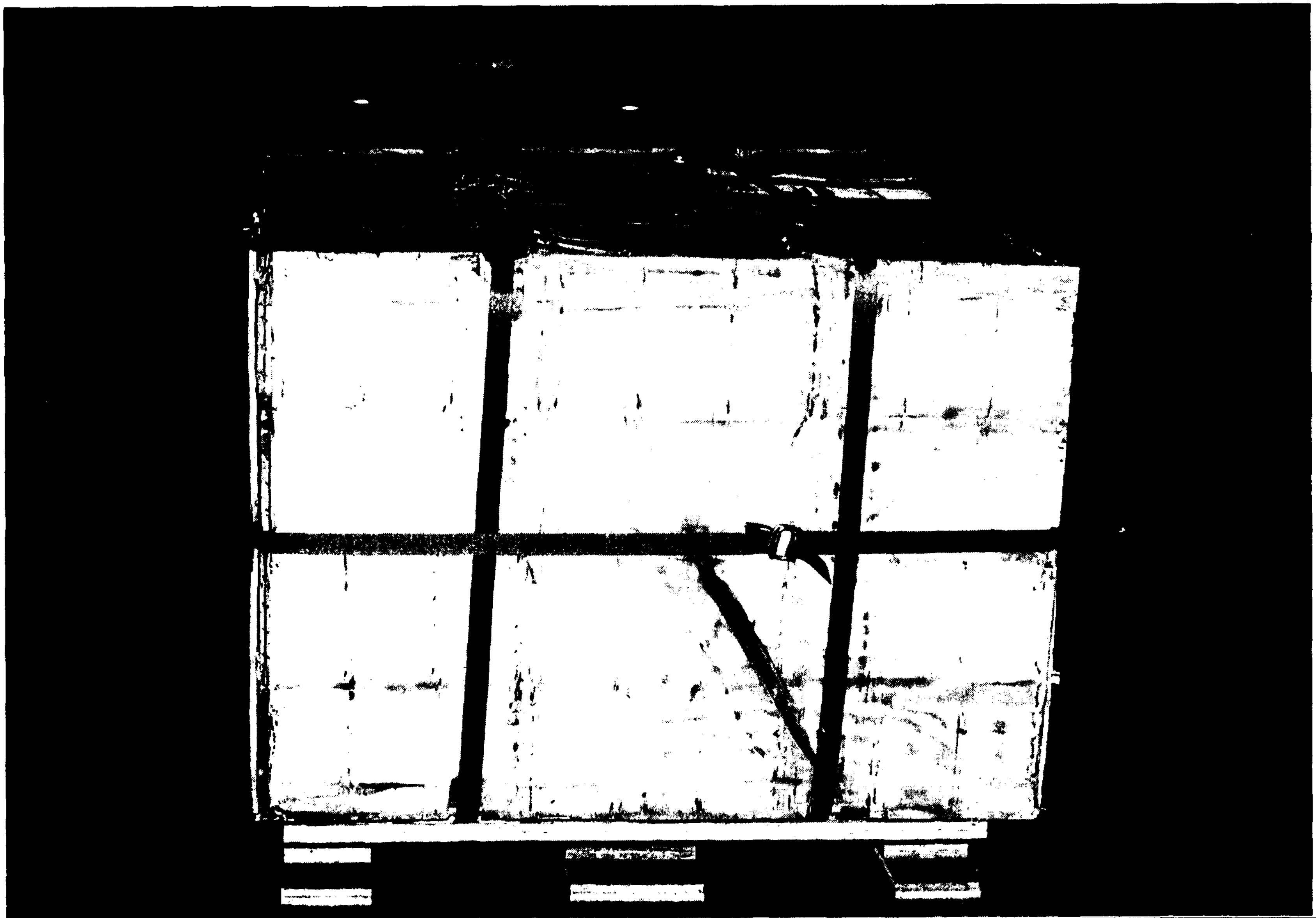


CARISTRAP APPLICATION



# PART 7

## PHOTOGRAPHS

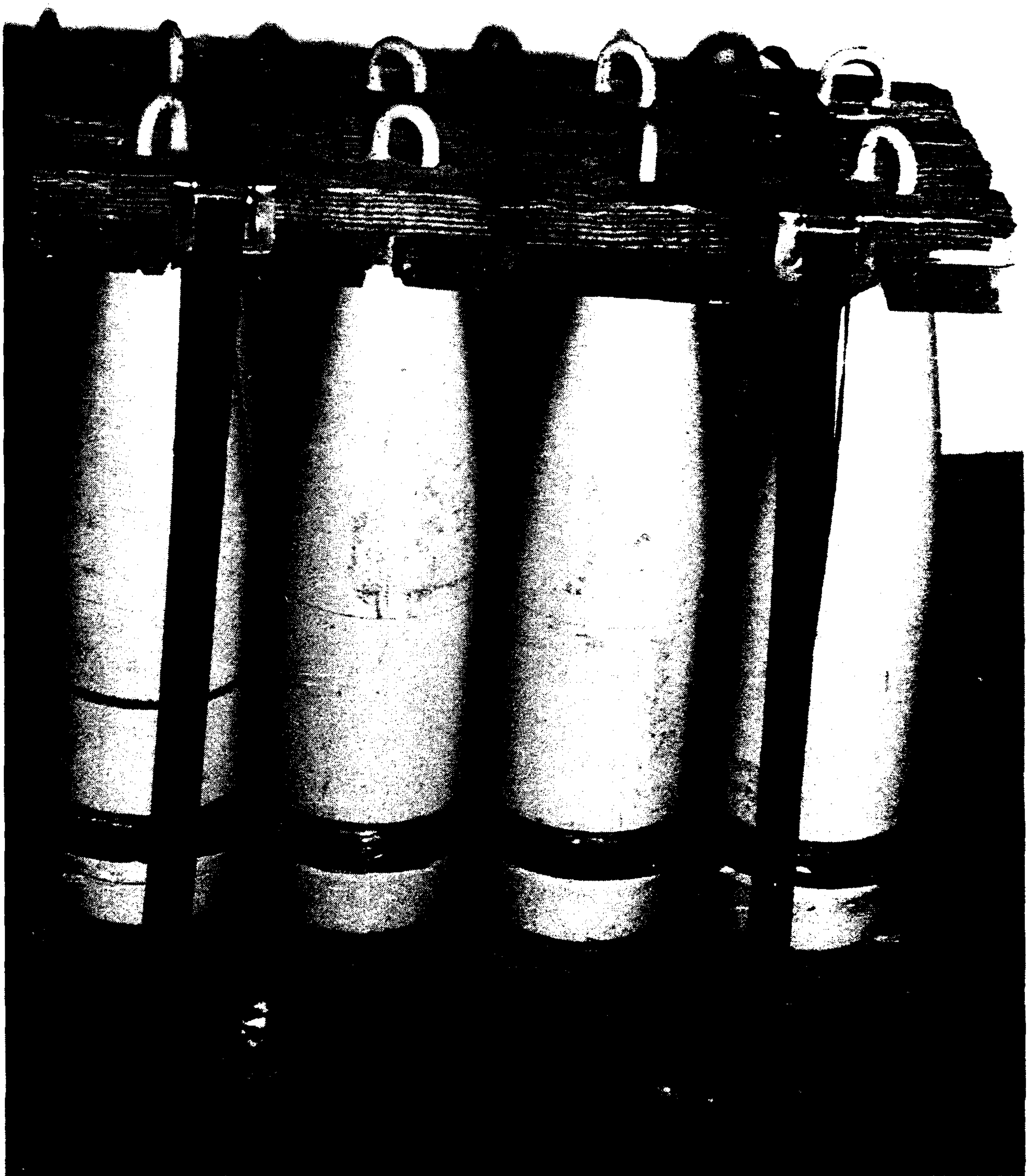


U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-1627. This photo shows the 4,000-pound inertly loaded plywood pallet unitized with Caristrap samples prior to MIL-STD-1660 testing.

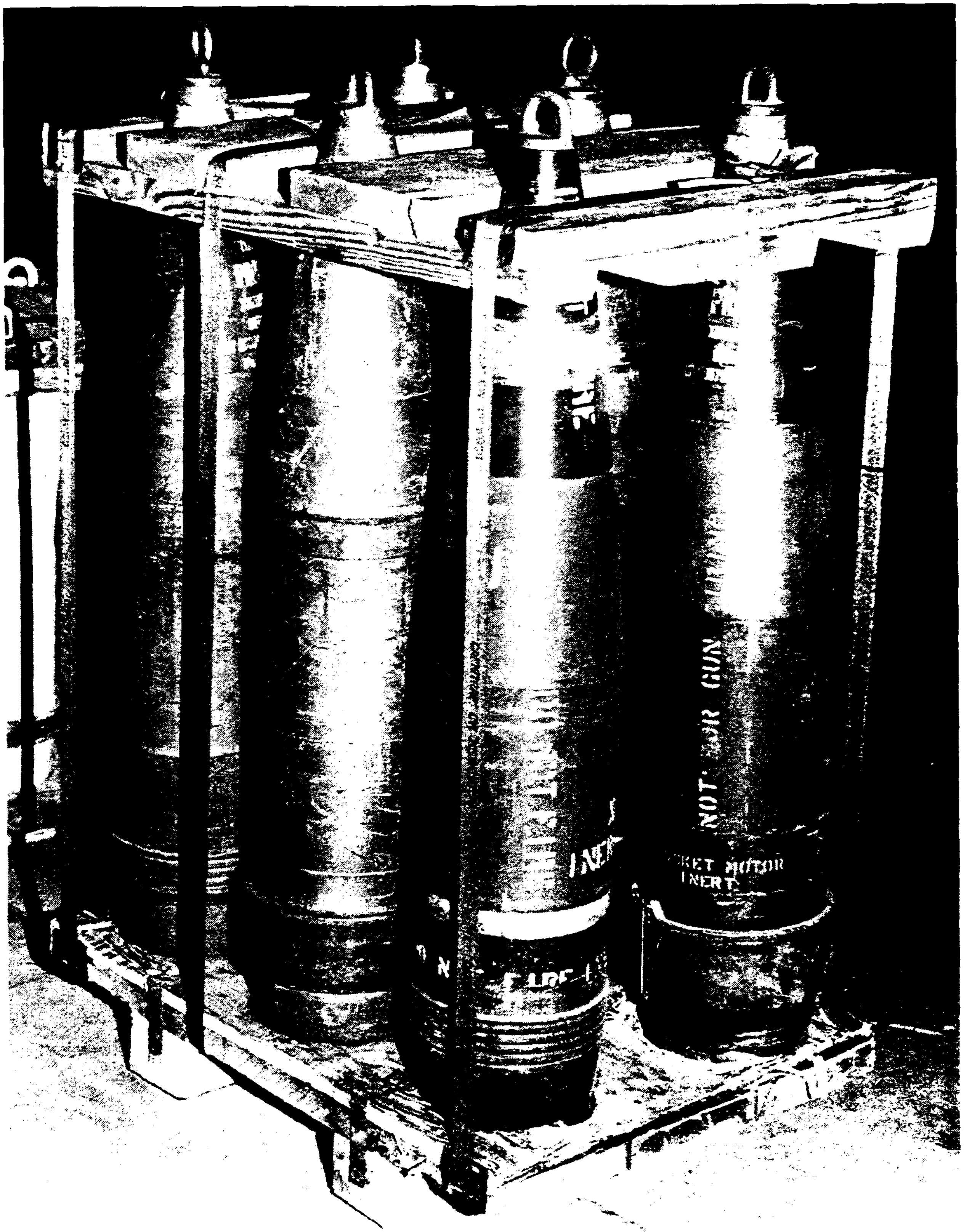
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-1626. This photo shows an additional view of the 4,000-pound loaded plywood pallet unitized with Caristrap samples prior to MIL-STD-1660 testing.



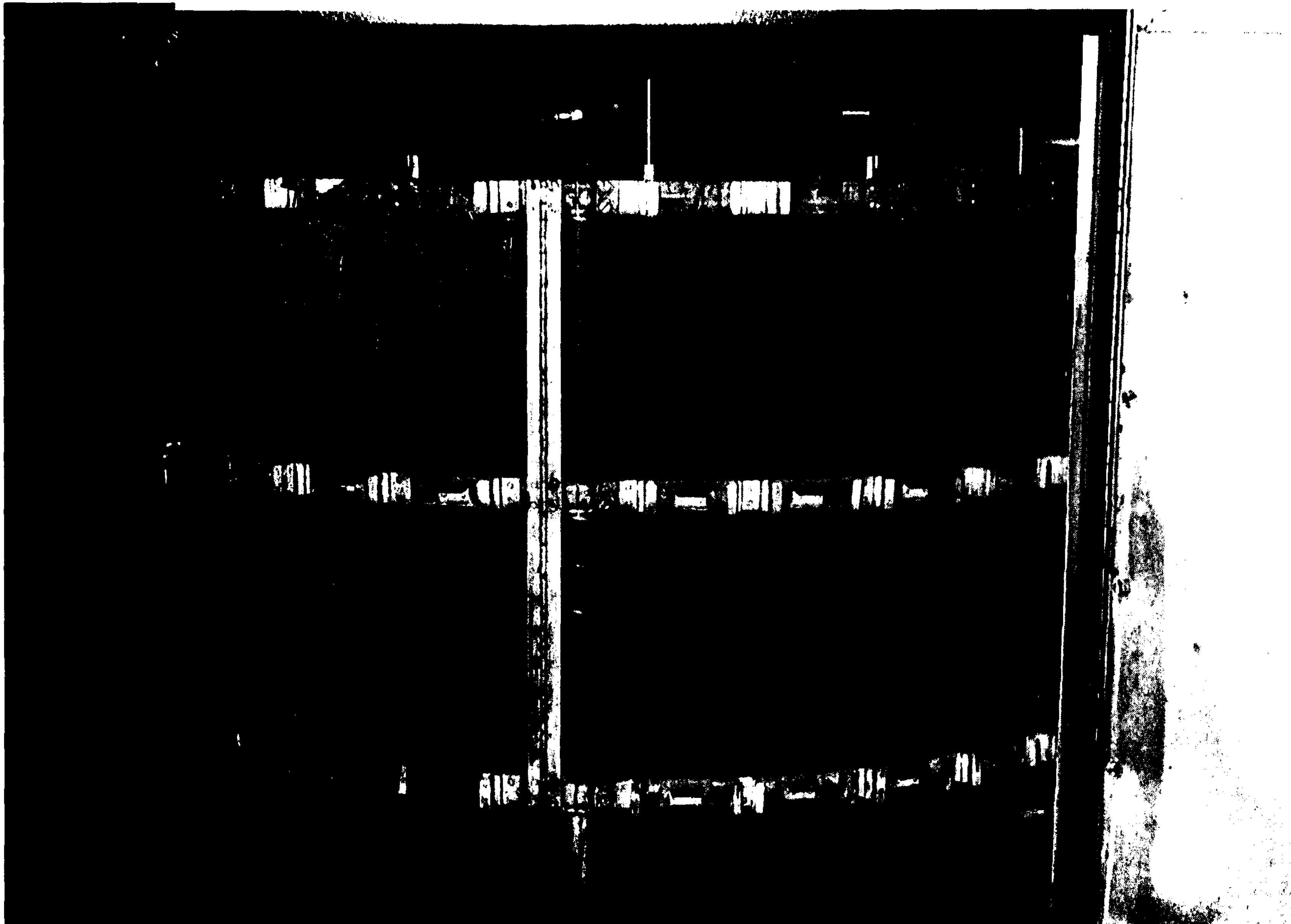
| | U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL | |
|---|---|---|

Photo No. AO317-SCN92-195-1956. This photo shows the 155mm projectile pallet unitized with Caristrap samples following MIL-STD-1660 testing.



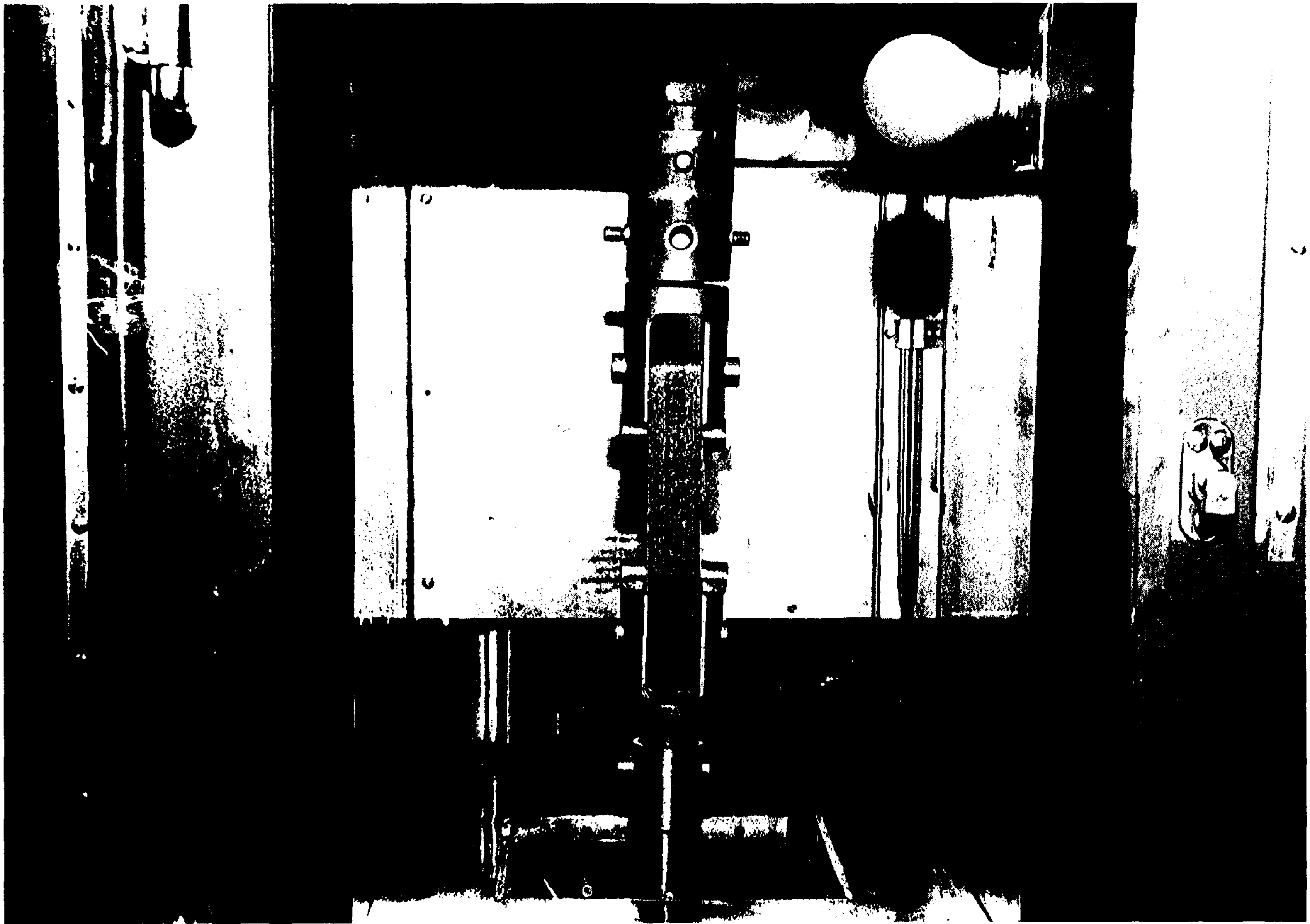
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-1957. This photo shows the 8-inch projectile pallet unitized with Caristrap samples following MIL-STD-1660 testing.



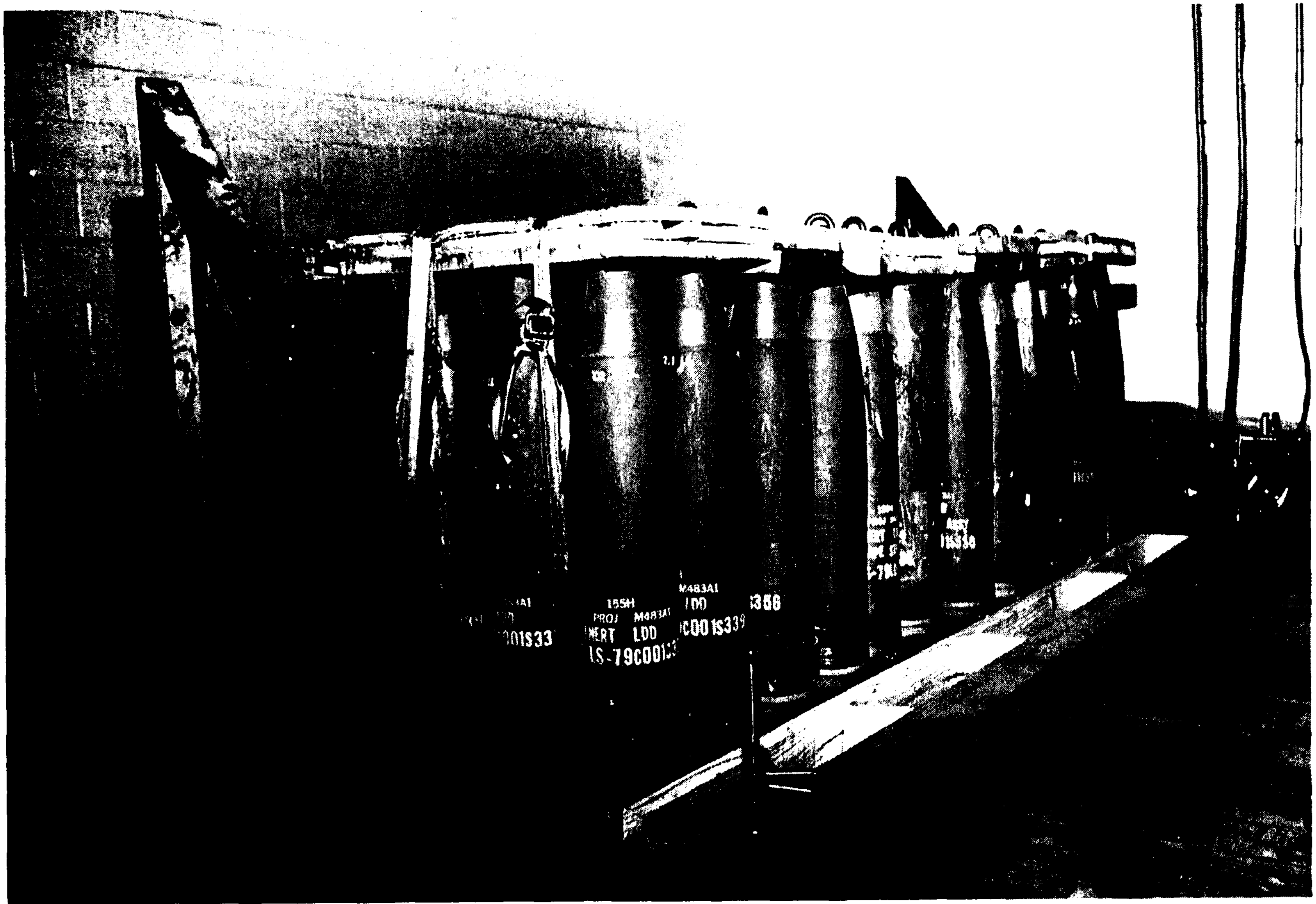
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-1631. This photo shows the inside of the weatherometer which was used to expose the Caristrap to UV light.



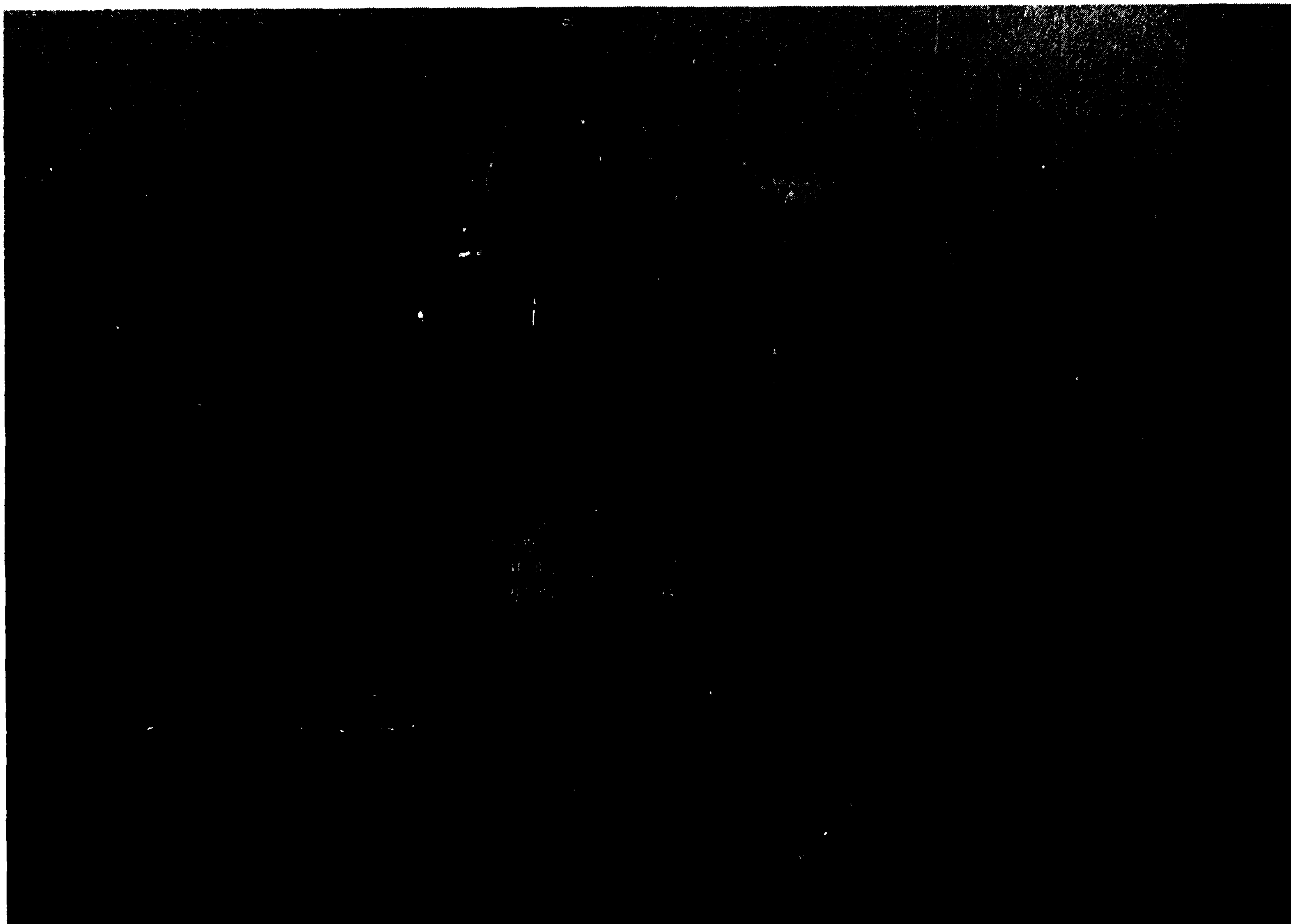
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-2717. This photo shows the tension/compression machine setup which was used to determine the tensile strength of the Caristrap.



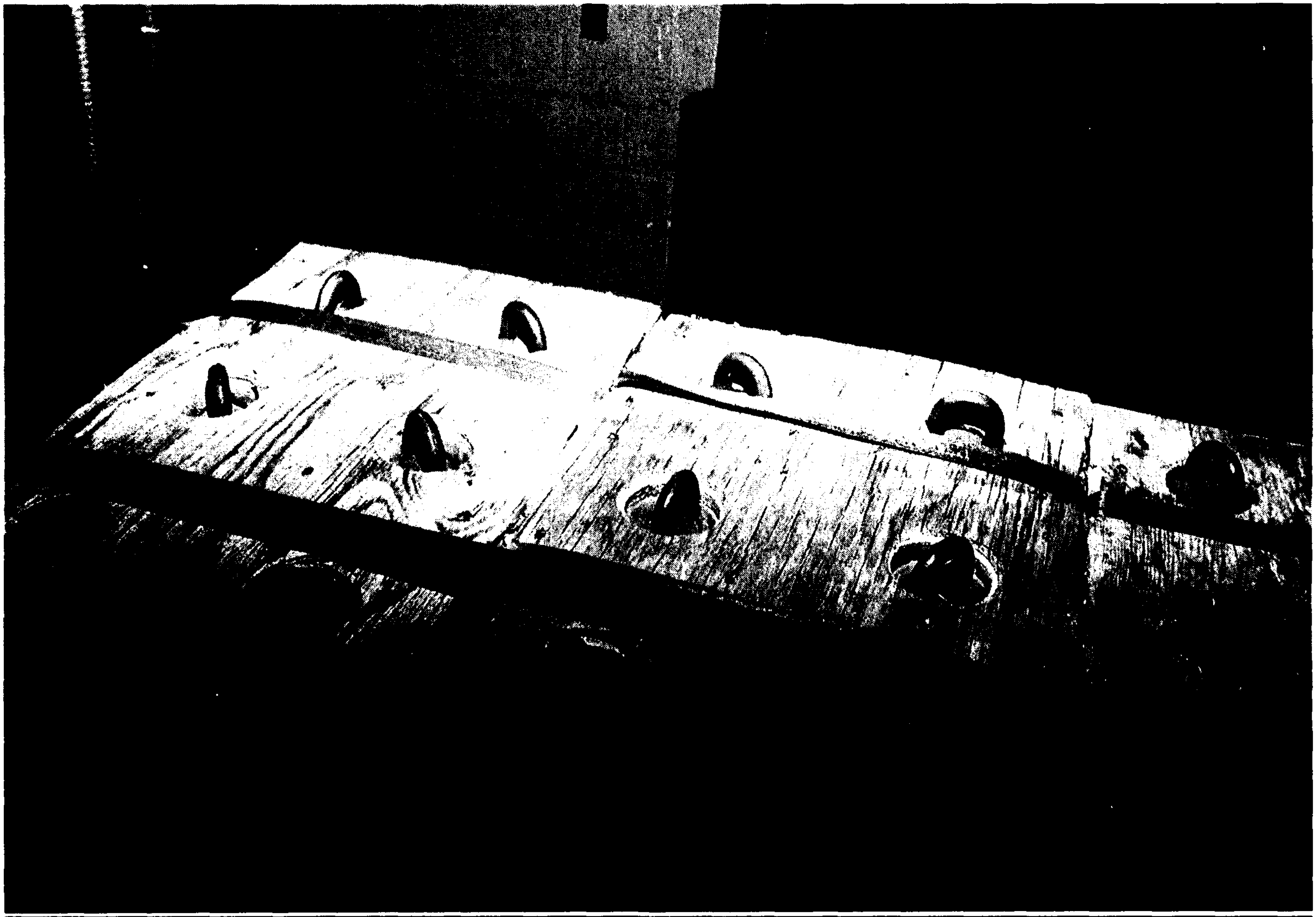

U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-2341. This photo shows the vibration table loaded with six 155mm projectile pallets for the perpendicular orientation of the truck transportation simulation.



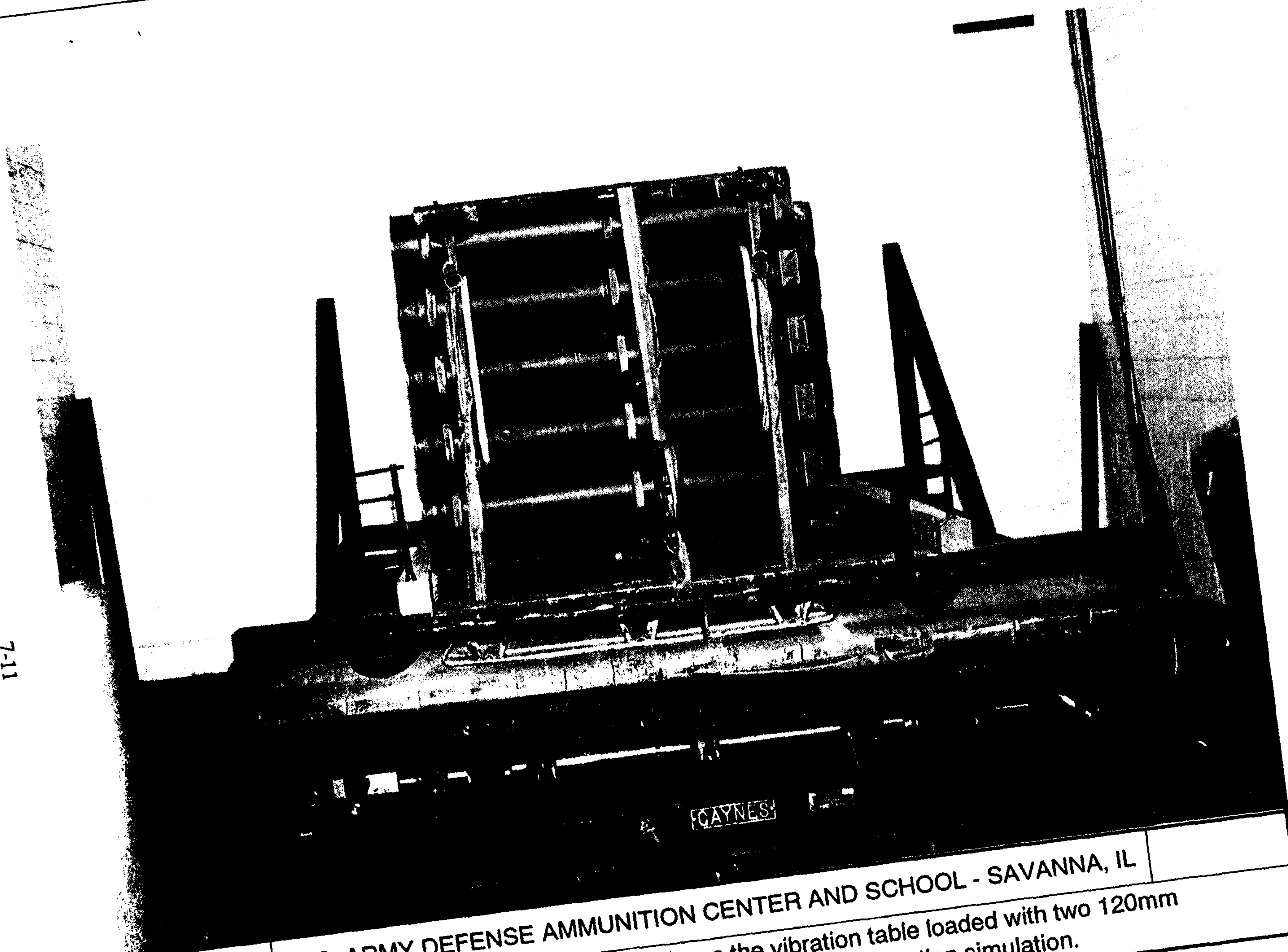
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-2704. This photo shows the vibration table loaded with six 155mm projectile pallets for the parallel orientation of the truck transportation simulation.



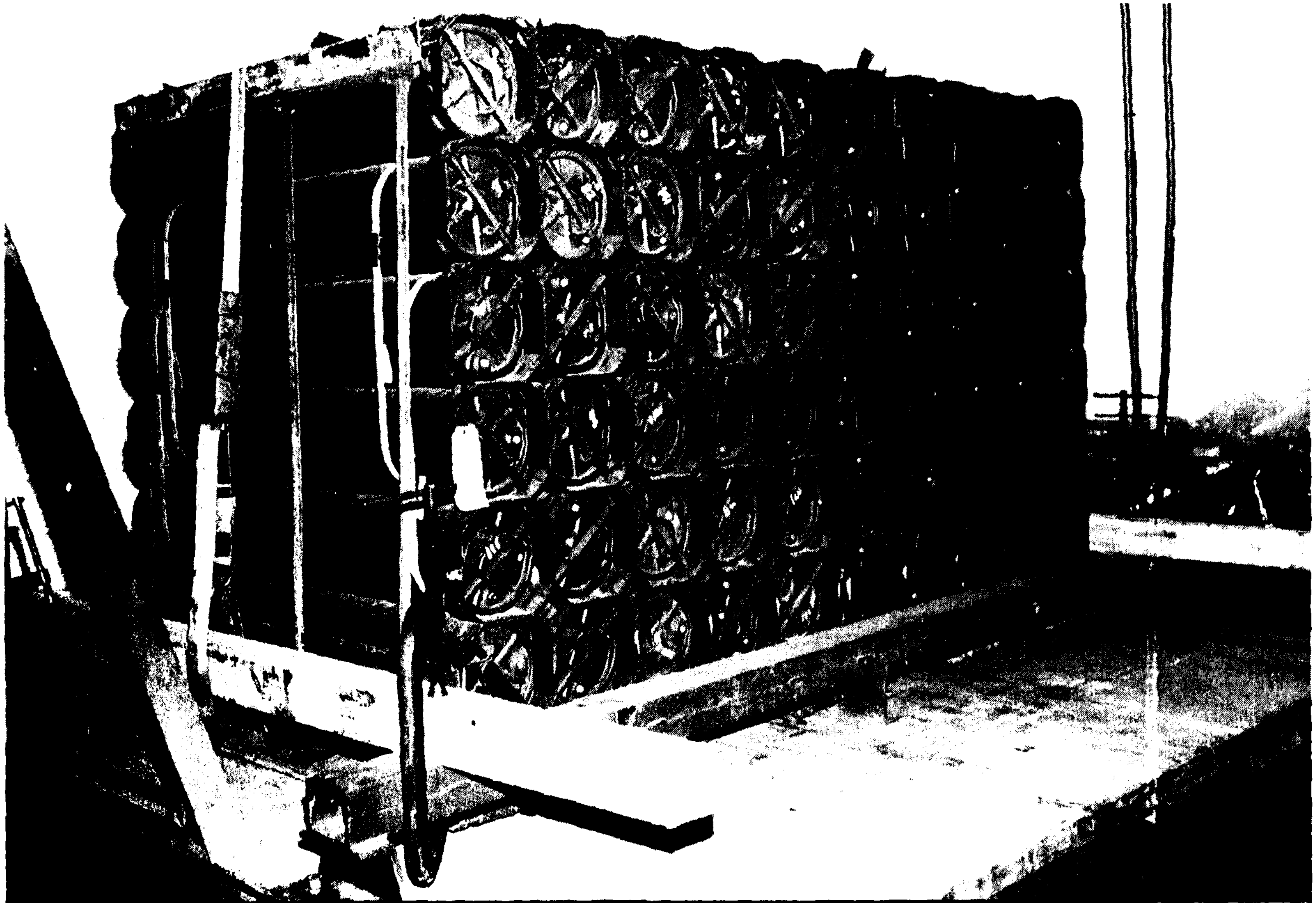
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-2343. This photo shows the condition of one of the Caristrap samples at the completion of just 6 minutes and 30 seconds of the first orientation of the truck transportation simulation.




U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2682. This photo shows the vibration table loaded with two 120mm ammunition metal pallets in the parallel orientation for the truck transportation simulation.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2690. This photo shows the vibration table loaded with two 120mm ammunition metal pallets in the perpendicular orientation for the truck transportation simulation.

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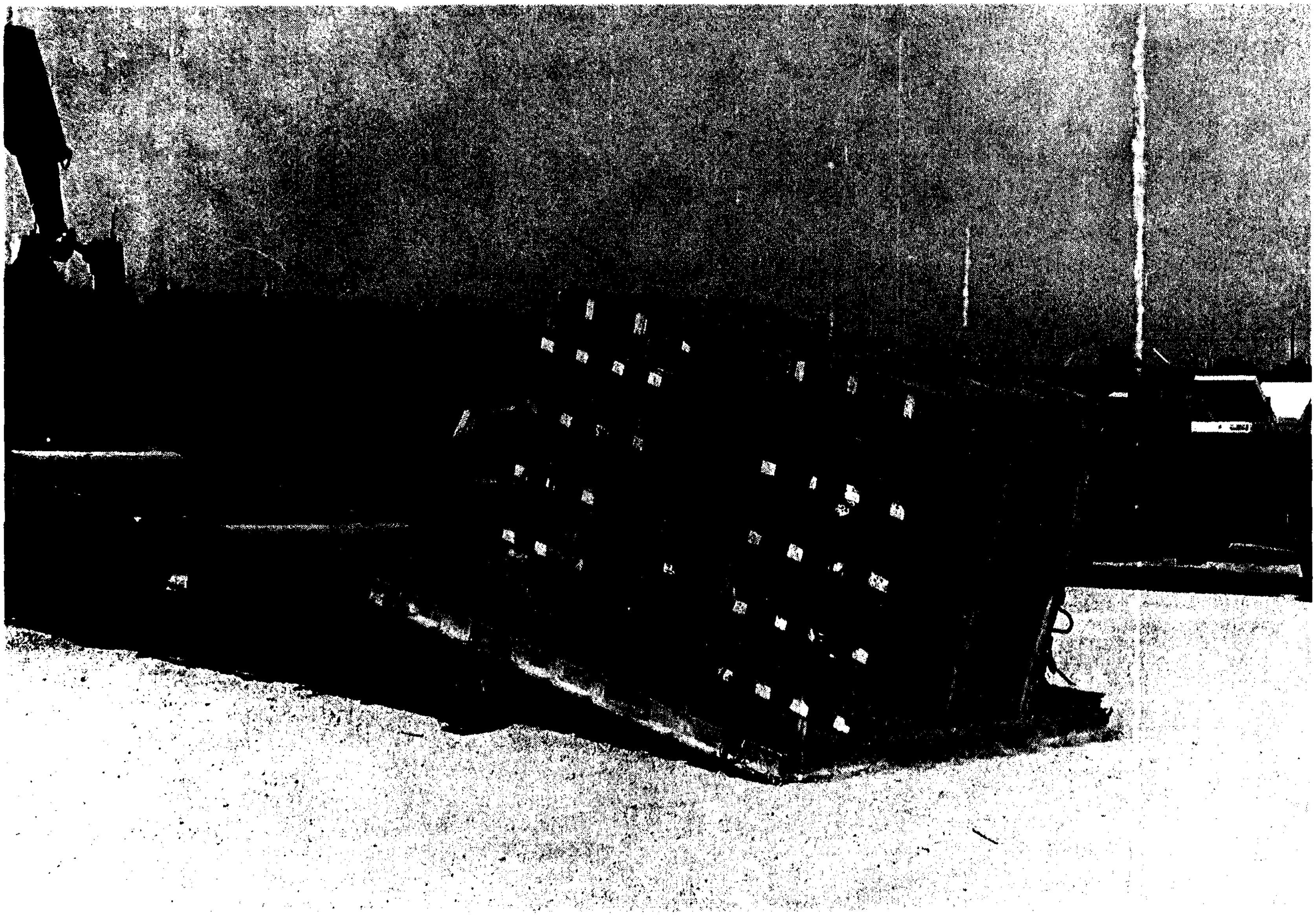
Photo No. AO317-SCN92-2853. This photo shows the ULARP loaded with Cobra Load II prior to incline-impact testing.



| U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL |
|---|
| Photo No. AO317-SCN92-195-2702. This photo shows the ULARP striking the ground during the incline-impact test. |


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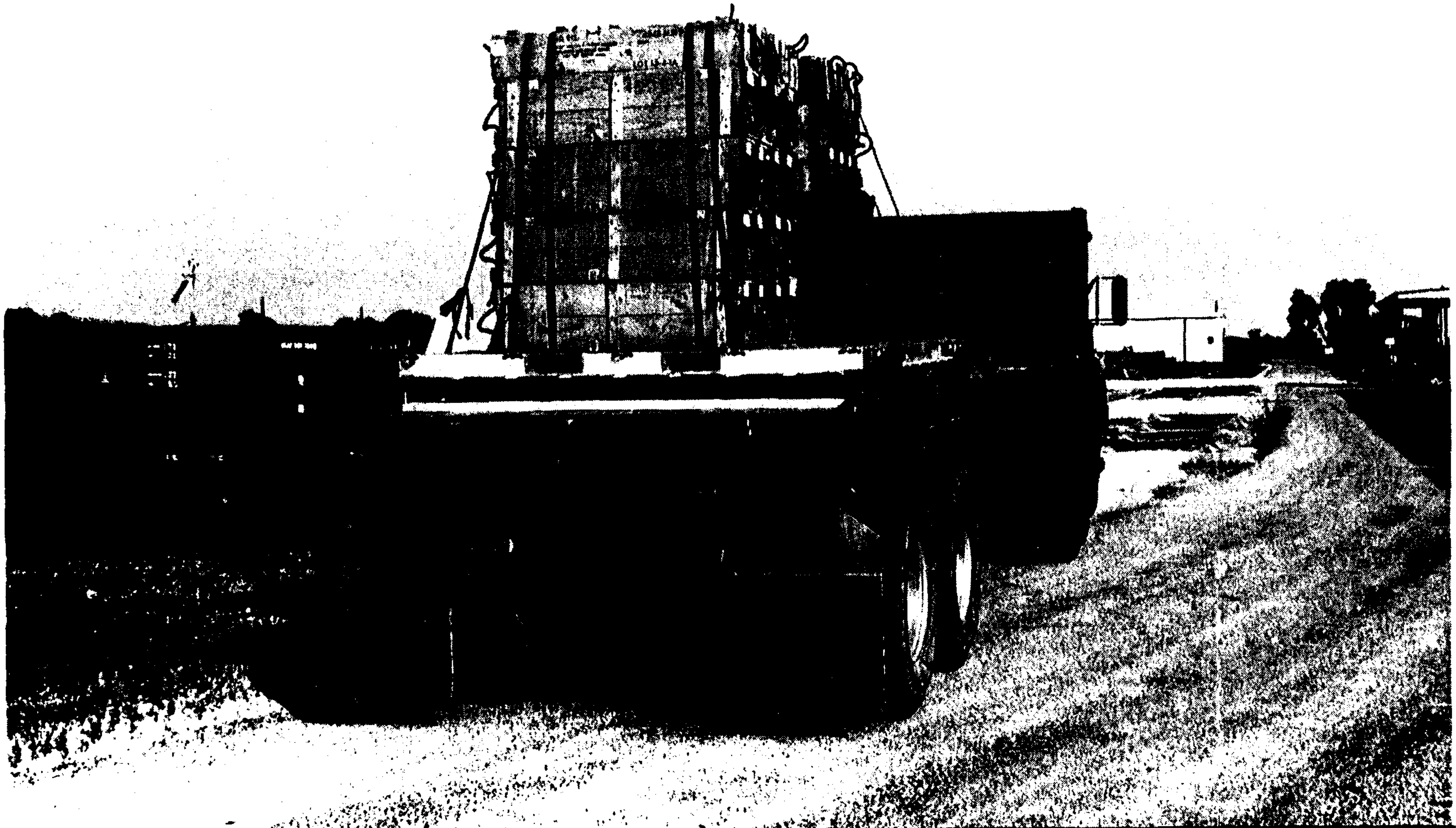
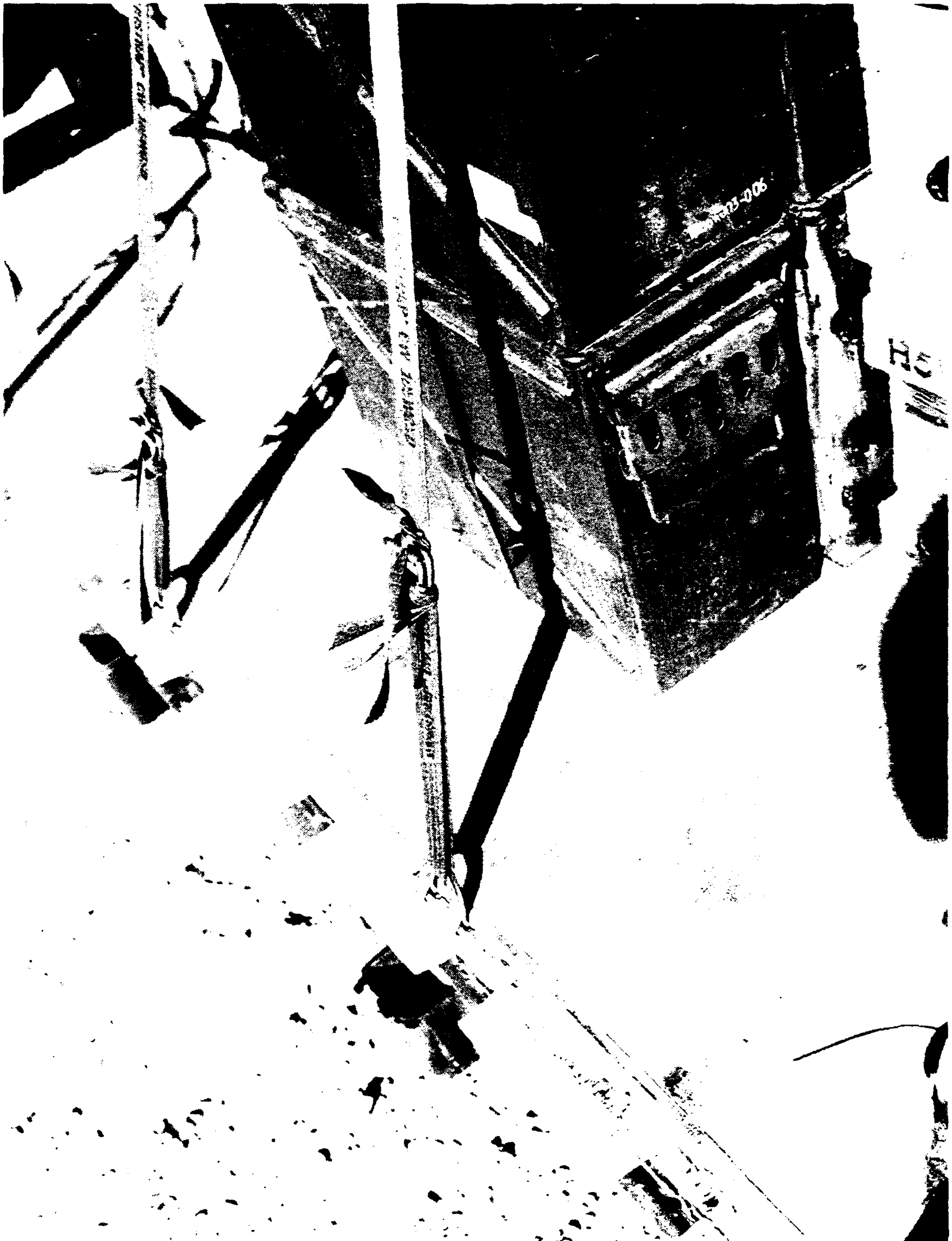
Photo No. AO317-SCN92-195-2860. This photo shows the ULARP attached to the M871 semitrailer prior to transportability testing.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2856. This photo shows the ULARP on M871 semitrailer approaching the road hazard course.



| | U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL | |
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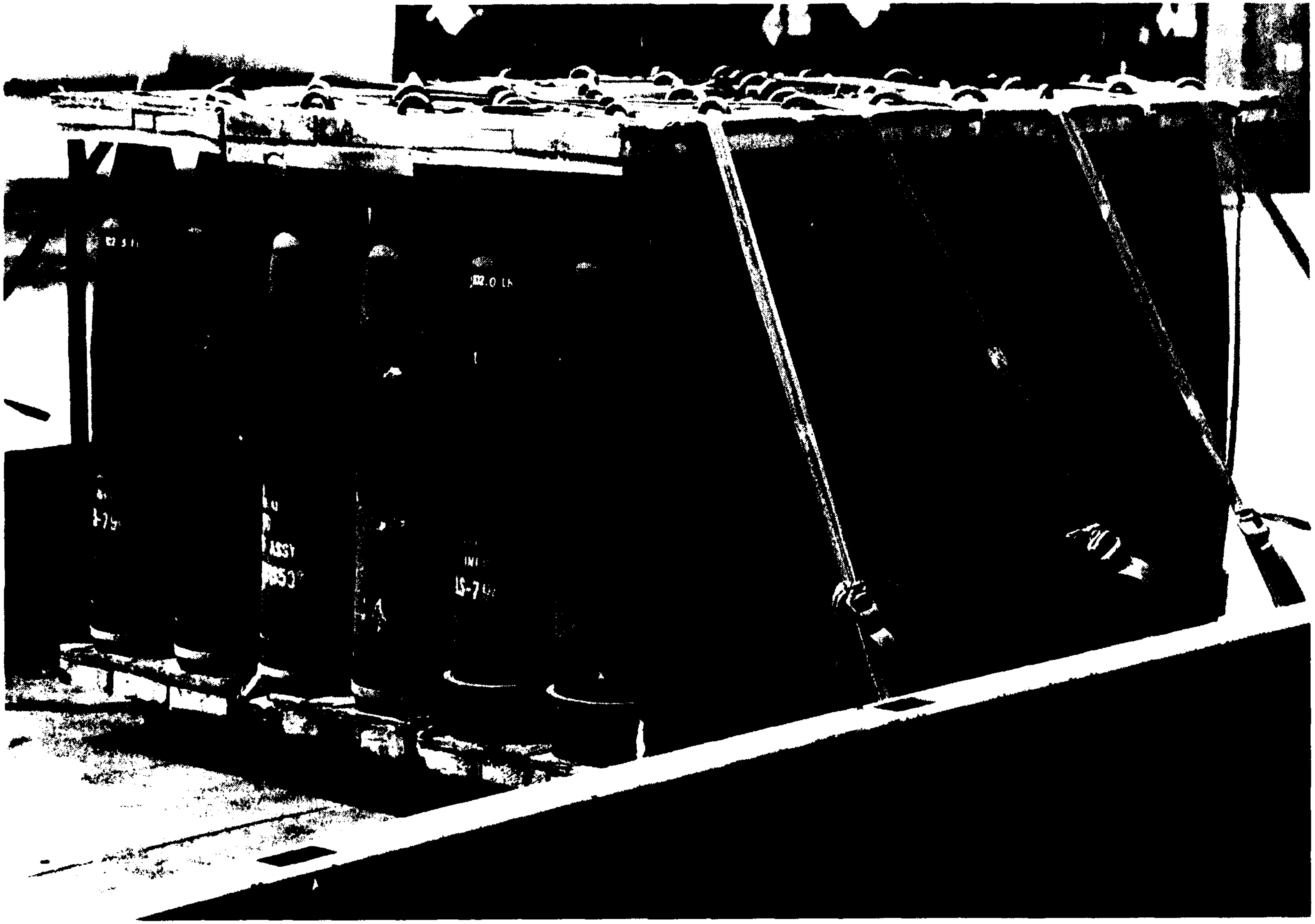
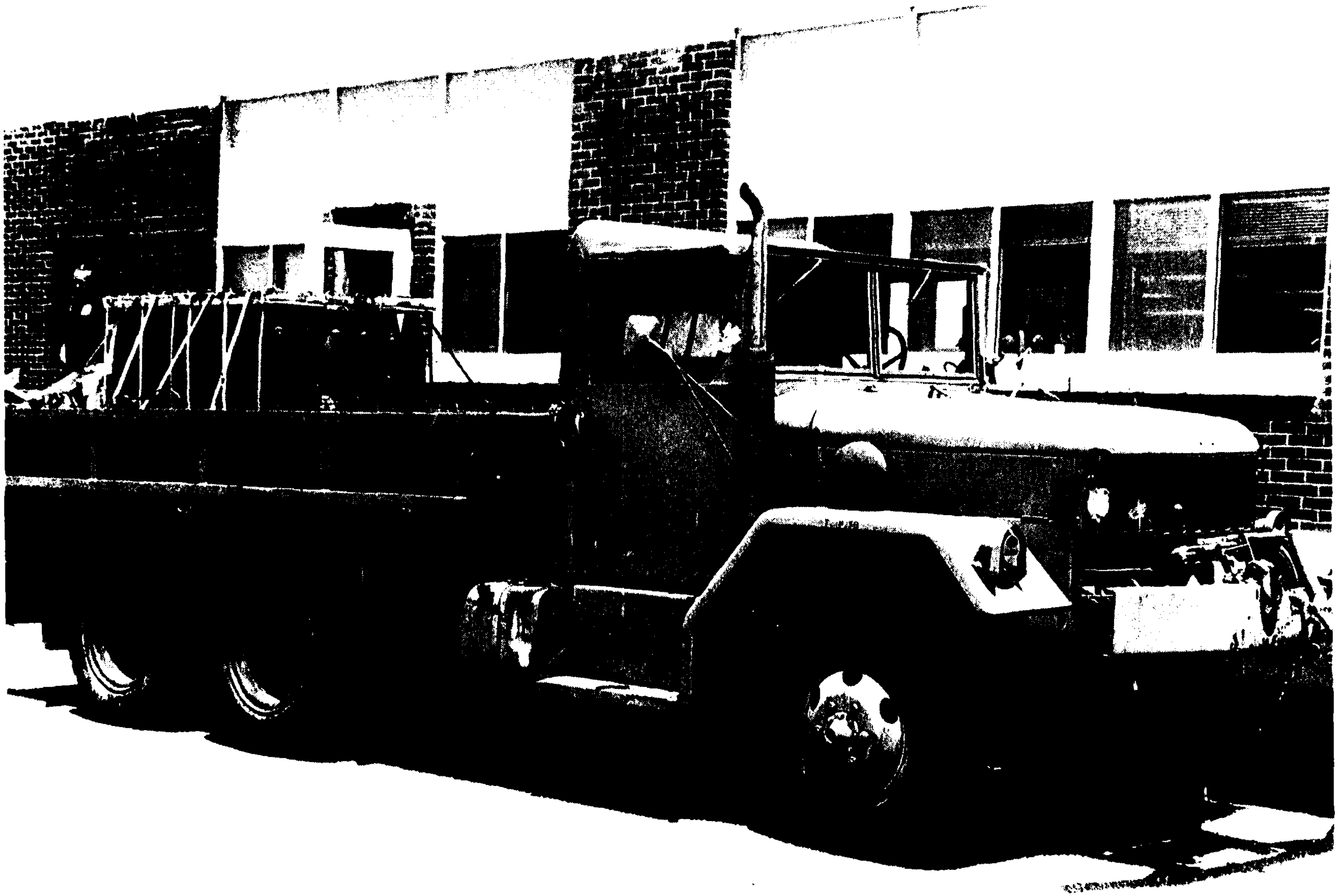
Photo No. AO317-SCN92-195-2849. This photo shows a closeup view of the Caristrap going through the ULARP tiedown anchor.



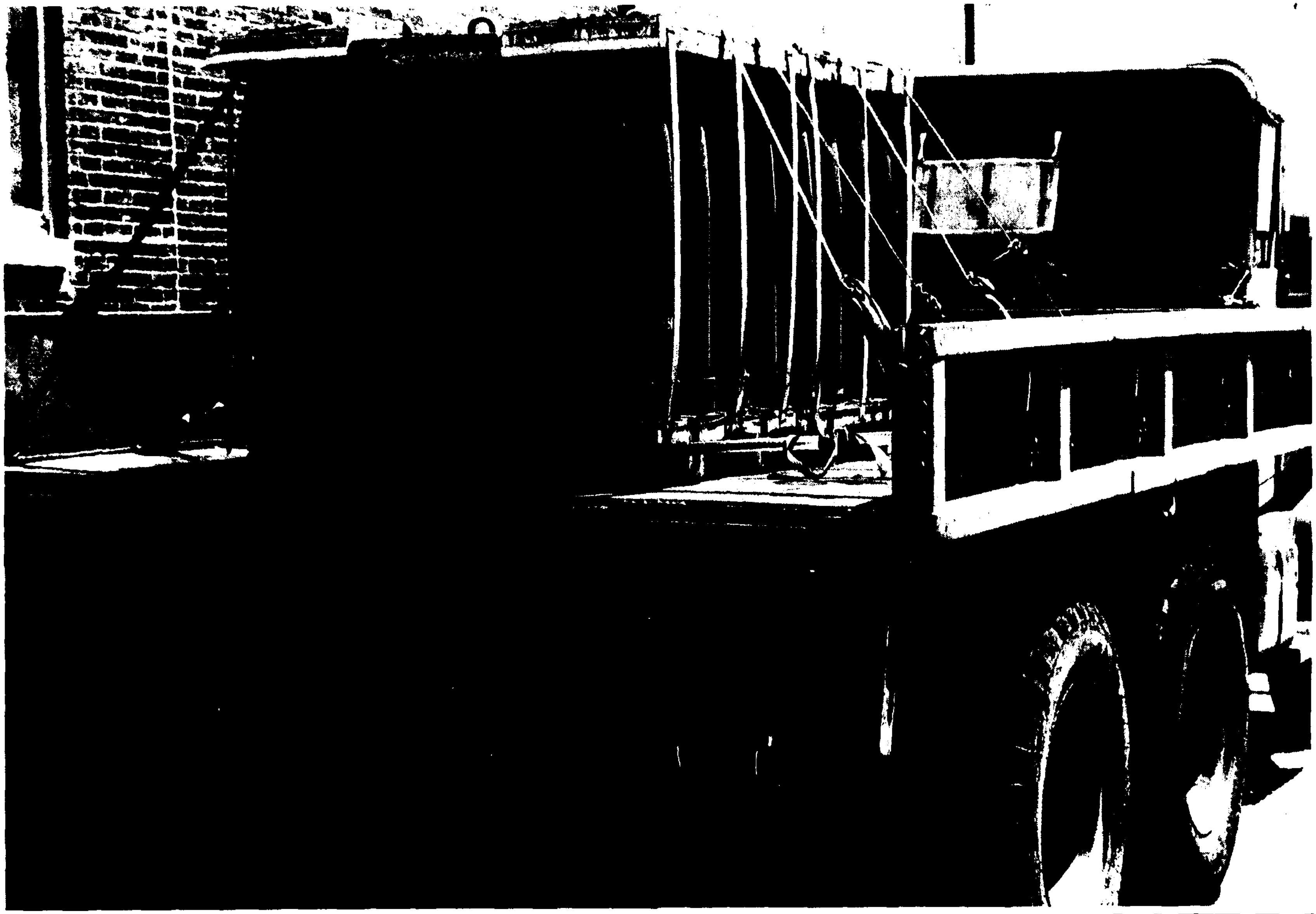
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2967. This photo shows the 155mm projectile pallets that were unitized with metal strapping and tied down with Caristrap samples in a 2-1/2-ton truck.



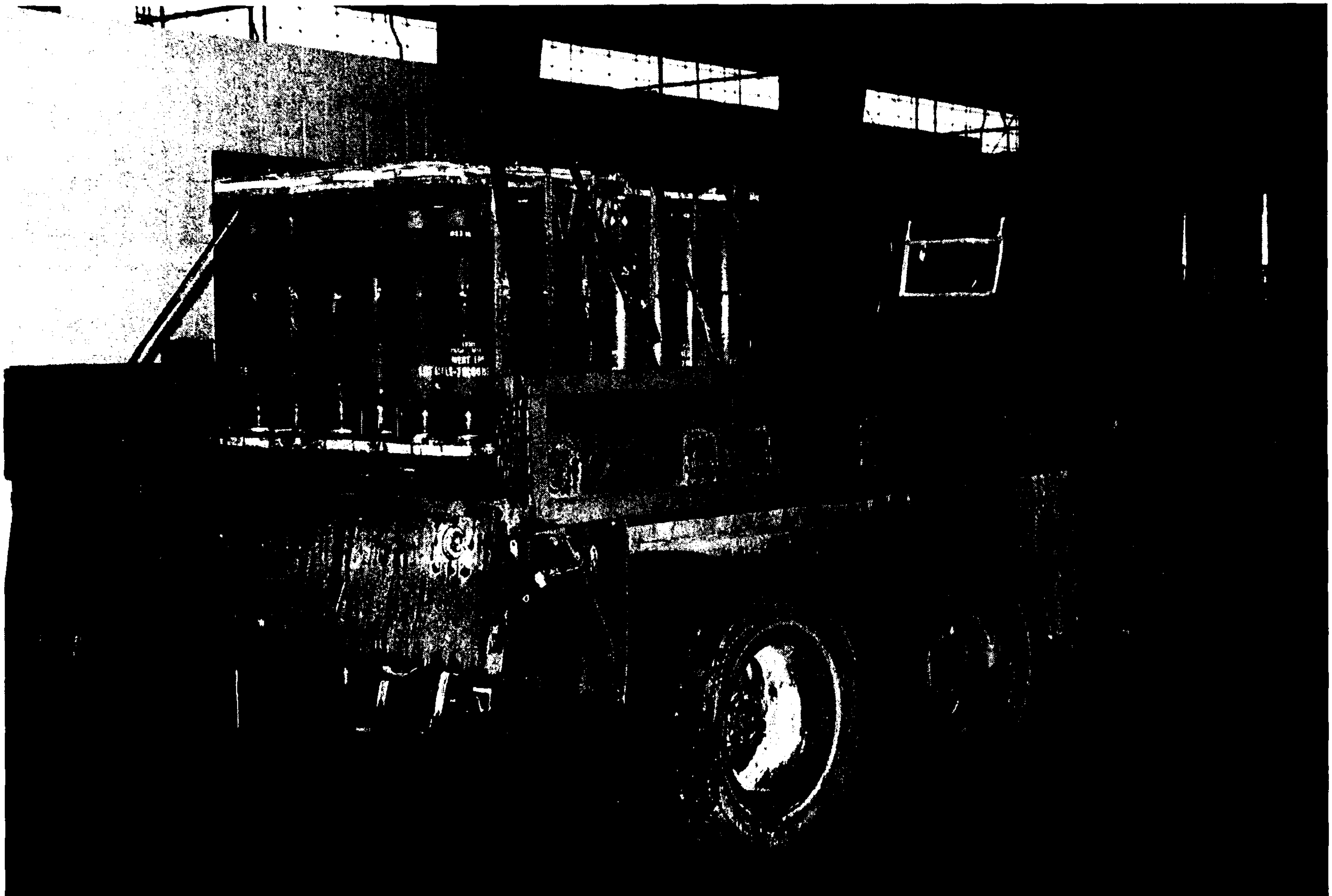
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2964. This photo shows an overall view of the 2-1/2-ton truck loaded with 155mm projectile pallets that were tied down with Caristrap samples.



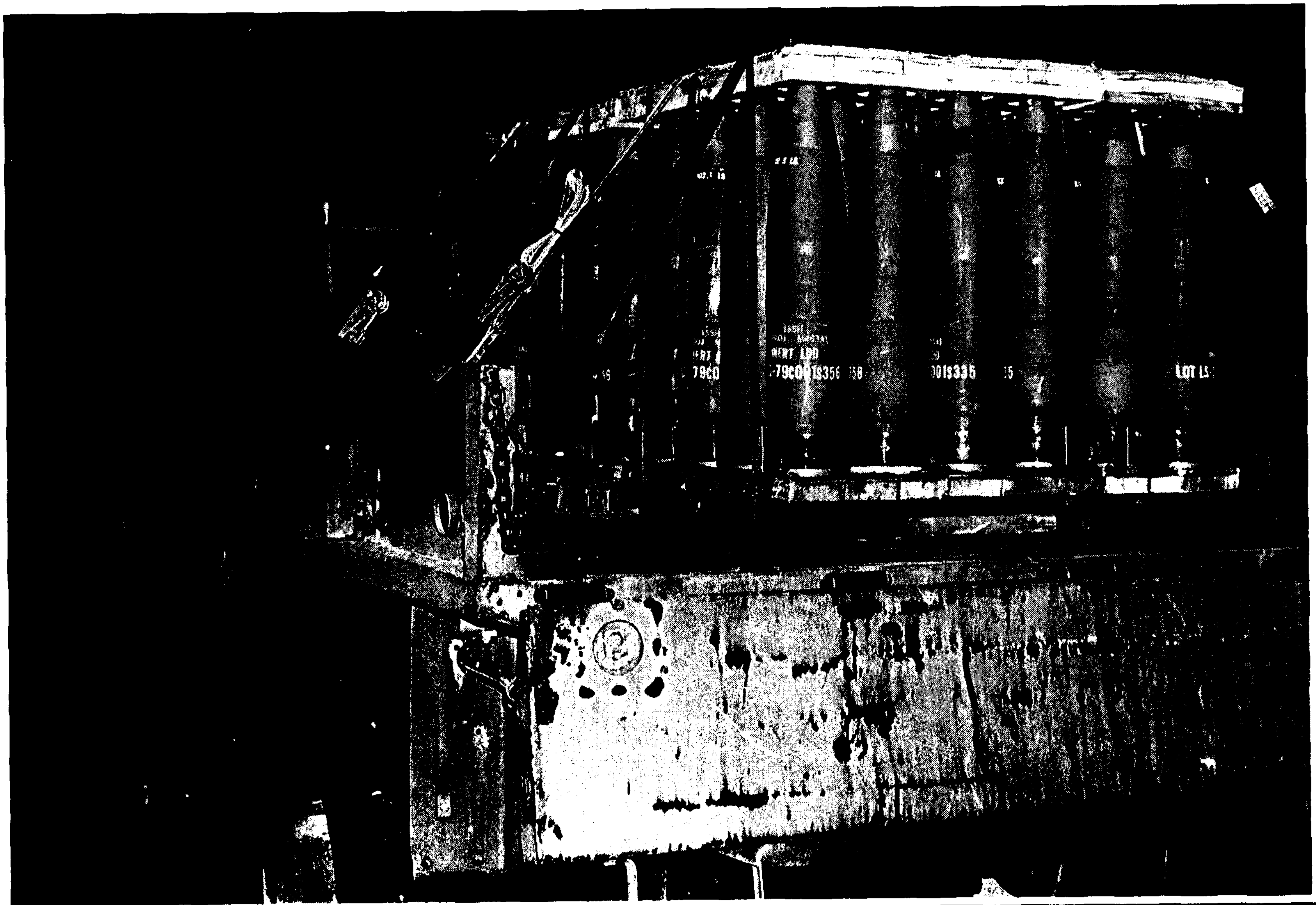
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN92-195-2965. This photo shows an additional view of the 2-1/2-ton truck loaded with 155mm projectile pallets that were tied down with Caristrap samples.



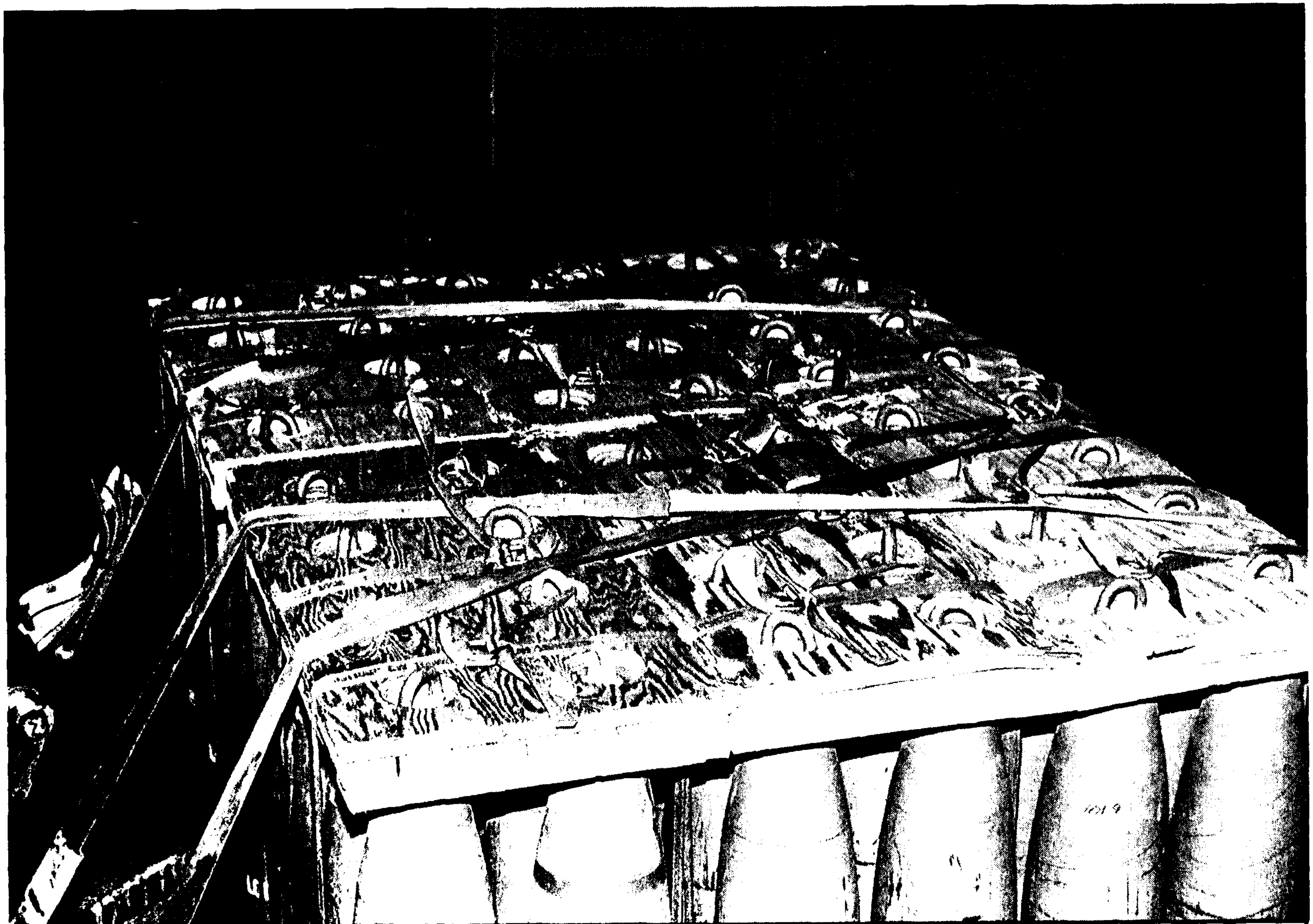
U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN93-22-144. This photo shows the 155mm projectile pallets that were unitized with Caristrap samples and tied down with web straps in a 2-1/2-ton truck.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN93-22-140. This photo shows an additional view of the 155mm projectile pallets that were unitized with Caristrap samples and tied down with web straps in a 2-1/2-ton truck.



U.S. ARMY DEFENSE AMMUNITION CENTER AND SCHOOL - SAVANNA, IL

Photo No. AO317-SCN93-22-145. This photo shows a closeup view of the top of the 155mm projectile pallets that were unitized with Caristrap samples and tied down with web straps in a 2-1/2-ton truck.